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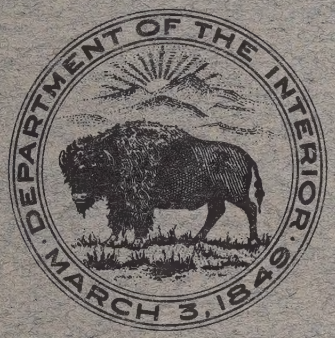
The PROGRESSIVE FISH-CULTURIST

Vol. 13 No. 4



OCTOBER 1951

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

THE PROGRESSIVE FISH-CULTURIST

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(See inside back cover)

The PROGRESSIVE FISH-CULTURIST

News and Views from many Sources on Practical Hatchery Problems

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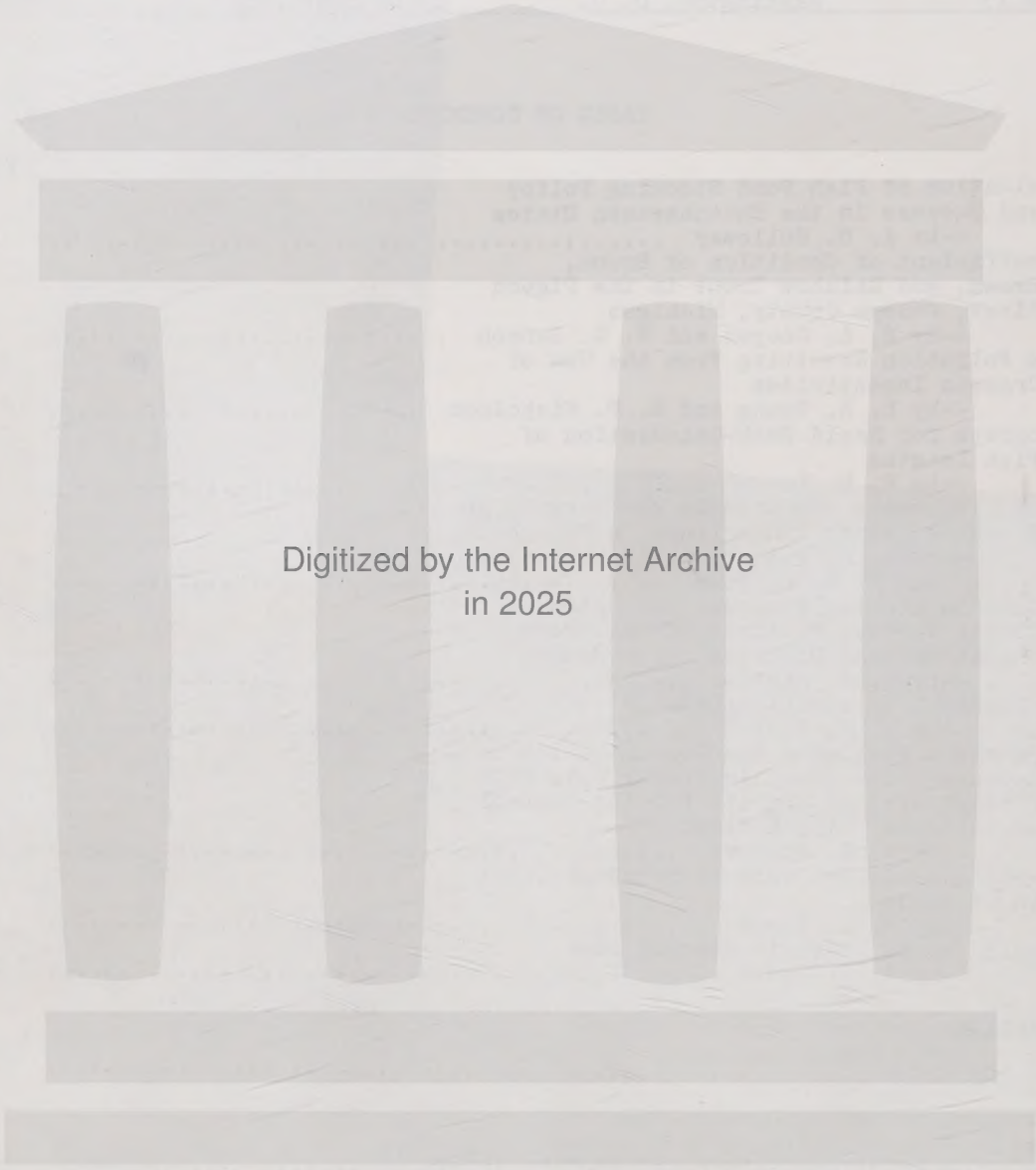

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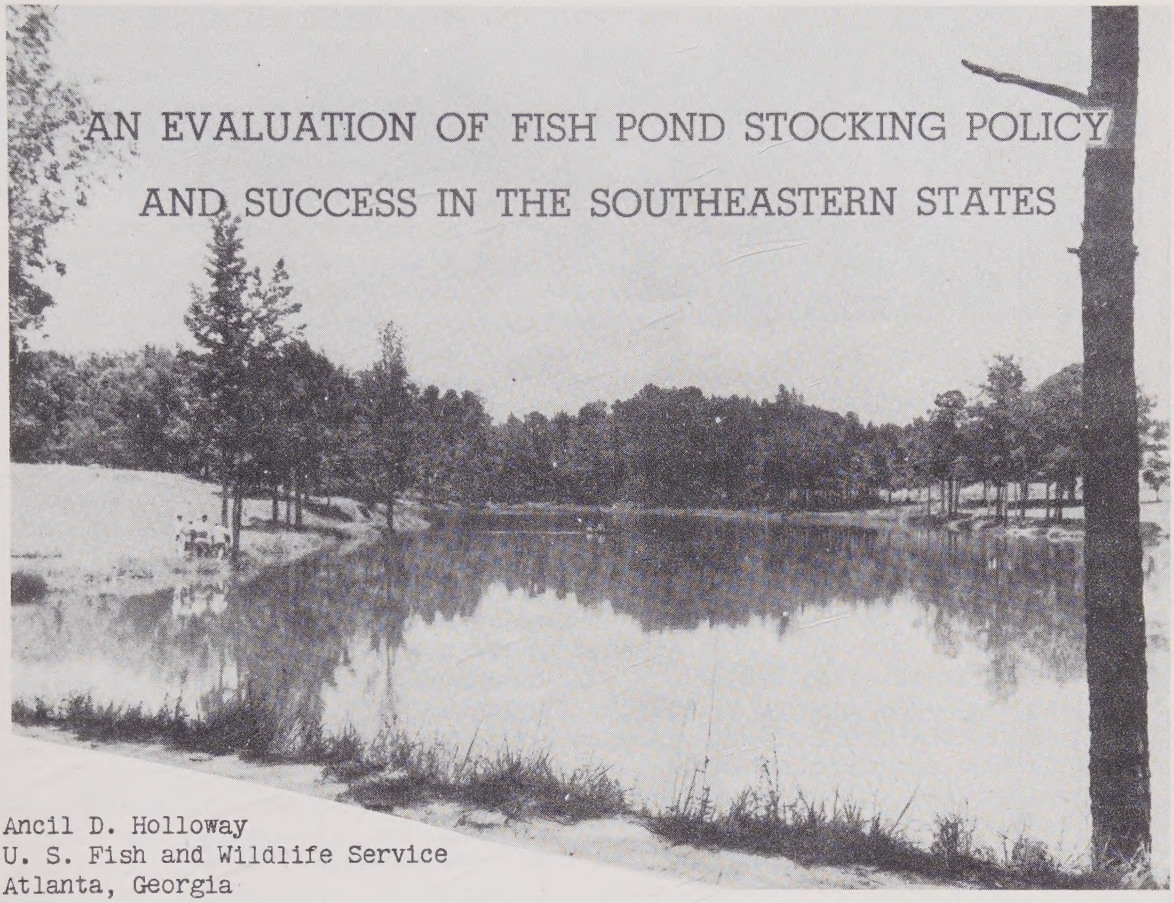


AN EVALUATION OF FISH POND STOCKING POLICY AND SUCCESS IN THE SOUTHEASTERN STATES

Ancil D. Holloway
U. S. Fish and Wildlife Service
Atlanta, Georgia

DURING THE last four summers an attempt has been made to examine a sufficiently large number of farm ponds to obtain a picture of the success of the farm-pond management program. During that period, records were filed on a total of 612 ponds. Of this number, 323 were examined as random samples, 200 by the author and 123 by Mr. Frank L. Snipes, of Tupelo, Mississippi. The ponds classified as random samples represented all ponds on a given route of travel predetermined from road maps. The road conditions, the number of ponds located on a given route, and the amount of time available influenced the selection of routes. The remaining 289 ponds were waters for which the owners requested advice.[1/]

[1/] These waters were examined by the author and the following project leaders: Glenn F. Adams, Elkmont, Alabama; Edward C. Blossom, Hoffman, North Carolina; Fred L. Cox, Mammoth Spring, Arkansas; Dudley B. Heiliger, Lyman, Mississippi; James W. McPhail, Orangeburg, South Carolina; C. M. Morefield, Natchitoches, Louisiana; Lloyd A. O'Neil, Corning, Arkansas; Thomas B. Reaves, Westover, Virginia; F. F. Tanner, Cohutta, Georgia; Meddie C. Walker, Cheraw, South Carolina.

All these men have received training in the analysis of fish populations in farm ponds under the direction of H. S. Swingle of Alabama Polytechnic Institute, Auburn, Alabama; in some cases, additional training was provided. All have proved their ability to analyze fish populations of the type found in farm ponds.

STOCKING RATES IN USE

The stocking policy of the U. S. Fish and Wildlife Service for new farm ponds in the Southeastern States is to plant 50 bass (Micropterus salmoides) and 500 bluegills (Lepomis macrochirus) per acre in unfertilized waters and 100 bass and 1,000 bluegills per acre in fertilized waters. These two stocking rates were

TABLE 1.--Analysis of 323 ponds sampled at random: their location, number, balance, turbidity, weed problem, and fertilization

State	Number	Balance				Turbidity		Vegetation		Fertilization	
		Bass heavy	Ideal	Static	Out of balance	Muddy	Clear	Weed problem	No weed problem	Weeds controlled	Inadequate to control weeds
Kentucky	18	0	4	7	7	0	18	3	15	0	18
South Carolina	32	2	2	28	0	0	32	20	12	2	30
Arkansas	42	7	20	9	6	9	33	3	39	10	32
Mississippi	138	3	51	70	14	5	133	14	124	24	114
Georgia	29	2	17	9	1	0	29	3	26	23	6
Tennessee	64	10	24	18	12	21	43	4	60	7	57
Total	323	24	118	141	40	35	288	47	276	66	257
Percent		7	36	44	12	11	89	14	85	20	79

selected after consultation with most of the technically trained personnel working on ponds in the Southeastern States at that time. Though many soil types occur in the region involved, the rates represented a considerable unanimity of opinion. The very limited data on carrying capacity of unfertilized ponds in the different soil types and under different ecologic conditions were a factor of importance. It was believed that understocking was more desirable than overstocking. Considered also were the funds available, which would not permit individual pond inspections.

The rate that is used by the U. S. Fish and Wildlife Service depends upon whether the owner of the pond indicates on the application form that the pond will or will not be fertilized. Data in table 1 indicate that only about 20 percent of the ponds are properly fertilized to justify the heavier stocking rate. Stocking rates differing from that of 100 bass and 1,000 bluegills per acre occurred in 26 of the 612 ponds examined.

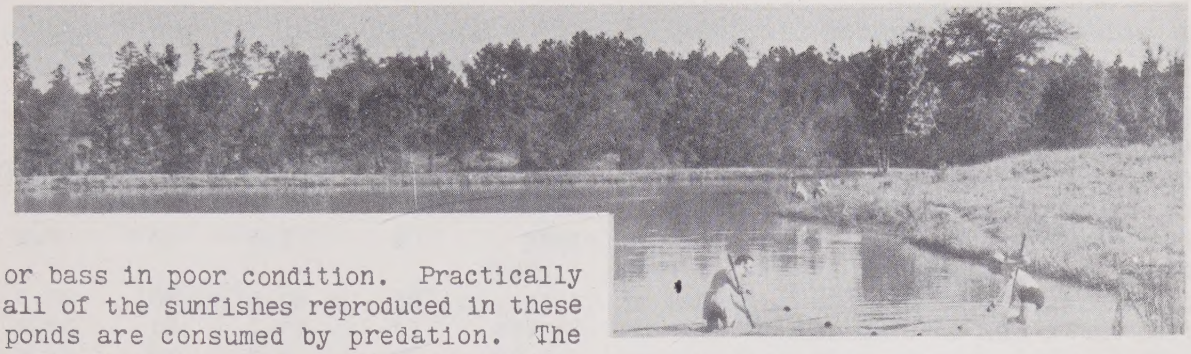
DISTRIBUTION METHODS

Ordinarily bluegills for a new pond are furnished during the late summer, fall, or winter months; bass are furnished the following spring, whenever they become available for harvest and are approximately 1 to 1.5 inches in length. Holloway (1947) outlined the stocking and distribution methods in general use by the U. S. Fish and Wildlife Service in the Southeastern States.

ORGANIZATION OF THE DATA

We have attempted to analyze the ponds on the basis of those sampled at random (table 1). As the ratio of predators (bass) to nonpredators (bluegills) is closely correlated with fishing success, an evaluation of the management methods and an understanding of the problem can best be achieved by placing the populations in four groups, each with specific characteristics as follows:

1. Bass Heavy.--The fish populations in this group show slow growth of bass,



or bass in poor condition. Practically all of the sunfishes reproduced in these ponds are consumed by predation. The bluegills make rapid growth and reproduce abundantly, but their volume is inadequate to provide food for normal growth of the bass and adequate escapement for replacements in the bluegill population. Nearly all of the bluegills are large adults. The weight ratio of bass to bluegills should be expected to be less than 1 to 2.7 (Swingle 1950). Ordinarily, fishing for both bass and bluegills is unsatisfactory under these conditions. Some ponds of this type may provide satisfactory fishing for bluegills if the conditions described are not too far advanced.

2. Ideal Balance.--These fish populations show adequate survival of bass and bluegills for replacements. All sizes of bluegills are present. Intermediate-size bluegills are not abundant. Only recently hatched bluegills are abundant during the spawning season. Rapid growth, heavy reproduction, and excellent fishing are obtained from both species. The weight ratio of bass to bluegills should be expected to fall between 1 to 3 and 1 to 6 (Swingle 1950).

3. Static.--These fish populations have a relatively large number of bluegills of intermediate size. Bass and bluegill reproduction occurs annually, but the reproduction of both species is much less than that found in ponds of ideal balance. Predation is inadequate. The overcrowding causes relatively slow growth of both bass and bluegills. The weight ratio of bass to bluegills should be expected to fall between 1 to 6 and 1 to 10 (Swingle 1950). The fishing is mediocre to very poor.

4. Out of Balance.--In these populations no bass or bluegills reproduced during the current year; or, a light bass reproduction may have occurred and the bluegills ceased to reproduce, because of overcrowding, before the usual spawning season was terminated. In most of these ponds, the weight ratio of bass to bluegills should be expected to be heavier on bluegills or other nonpredators than in static ponds.

PONDS EXAMINED AS RANDOM SAMPLES

Of the 323 ponds examined as random samples, 7 percent were bass-heavy, 36 percent were in ideal balance, 44 percent were in static condition, and 12 percent were too heavy on nonpredators (table 1). These figures suggest a success ratio of approximately one pond out of every three stocked.

Eleven percent of the ponds were classified as muddy and were of little value as fish ponds regardless of the balance of the fish population.

Fourteen percent of the ponds had weed problems. This is believed to be the condition causing all of these ponds to be classified in either the static group or the out-of-balance group.

In 20 percent of the ponds, adequate fertilizer had been applied. The resulting turbidity controlled the weeds except in water less than about 18 inches in depth. The 20 percent figure may be slightly high, as 23 of the 24 ponds examined in one soil conservation district near Columbus, Georgia, were fertilized. If these 24 ponds were omitted from the samples, the figure would be lowered to approximately 16 percent (which is thought to be nearer the true figure).

Ordinarily ponds with fish populations in ideal balance provide better angling if fertilized than if unfertilized. This may be due to darker water, increased carrying capacity, and other factors,

especially the increased frequency of feeding in fertilized waters. We feel that the success of angling in fish populations of ideal balance, as compared with the success in static or out-of-balance fish populations, is directly related to the frequency of feeding to which the fishes are accustomed. Other factors being equal, a pond with a static fish population should carry more pounds of fish than a pond in ideal balance; but the pond in ideal balance, with rapidly growing fish, provides far superior angling and larger harvests.

TABLE 2.--Analysis of 323 ponds sampled at random: their balance and fertilization to control weeds

Balance	Fertilized		Unfertilized	
	Number	Percent	Number	Percent
Bass heavy	1	1.5	23	8.9
Ideal	53	80.3	65	25.3
Static	10	15.1	131	50.9
Out of balance	2	3.0	38	14.8
Total	66	99.9	257	99.9

THE VALUE OF PROPER FERTILIZATION

Table 2 demonstrates the importance of proper fertilization to establish an ideal balance in the fish population when the stocking rate of 100 bass and 1,000 bluegills is used.

Only 1 fertilized pond (1.5 percent of the 66 fertilized ponds) is rated as bass-heavy, whereas 23 unfertilized ponds (8.9 percent of the 257 unfertilized ponds) are so rated.

The populations of 53 fertilized ponds (80.3 percent of the fertilized group) are classified as showing ideal balance, but only 65 unfertilized ponds (only 25.3 percent of the unfertilized group) are so classified.

Only 10 fertilized ponds (15.1 percent of the fertilized group) are listed as being static, but 131 unfertilized ponds (50.9 percent of the unfertilized group) are so listed.

Only 2 fertilized ponds (3 percent) are in the out-of-balance group, while 38 unfertilized ponds (14.8 percent) are shown in this category.

The information on static unfertilized ponds suggests that many of these ponds could come into ideal balance with proper fertilization. This is true, however, only for those ponds that can be fertilized economically. In some, fertilization is prevented by excess flows, silt, large size, or faulty structure.

The primary cause for the appearance of such a large number of ponds in the static group, when they are 4 years of age or older, is believed to be lack of weed control. The primary cause of static populations in ponds 2 and 3 years old is believed to be too heavy stocking for the carrying capacity; lack of weed control is believed to be a contributary cause. All but 6 of the 323 random-sample ponds are believed to have been stocked at the rate for fertilized ponds (100 bass and 1,000 bluegills per acre), while only 66 (20 percent) of the ponds were fertilized adequately to control weeds.

The data on 418 problem ponds (table 3) suggest even more strongly that an extremely important factor preventing ponds from coming into ideal balance is too heavy stocking for the natural carrying capacity of the ponds. Only 18 were stocked at rates other than 100 bass and 1,000 bluegills per acre. In a few ponds, crappie (Pomoxis) were substituted for as much as 25 percent of the bass allotment. Likewise, redear sunfish (L. microlophus) were substituted for 50 percent or less of the bluegill allotment, and in some ponds brown bullheads (Ameiurus nebulosus marmoratus) were substituted for as much as 15 percent of the bluegill allotment. The success rate in such ponds is equivalent to that in ponds without the substitutions. They occur in such small numbers that they neither add to nor subtract from the validity of the argument at hand.

The largest group of problem ponds (67 percent) were classified as static. This group would derive the greatest benefit from proper fertilization. It is significant that 90 percent of the problem ponds were unfertilized and only 10 percent were fertilized.

TABLE 3.--Analysis of 418 problem ponds: their balance and fertilization

Balance	Number	Percent	Fertilized		Unfertilized	
			Number	Percent	Number	Percent
Bass heavy	33	8	3	7.1	30	8.0
Static	280	67	24	57.1	256	68.0
Out of balance	105	25	15	35.7	90	23.9
Totals	418	-	42	10.0	376	90.0

CARRYING CAPACITY AND STOCKING NEEDS

An understanding of the relation of carrying capacity to stocking needs can best be obtained by exploring the characteristics of ponds that provide excellent fishing and the methods of determining stocking rates that can be expected to provide the desired results.

Swingle (1950) shows the importance of proper stocking and outlines the qualifications for successful fish ponds as follows:

1. The desirable predator-nonpredator weight ratio must fall between 1 to 3 and 1 to 6. Ratios near 1 to 4 were apparently the most desirable in fertilized ponds for the production of larger poundage of harvestable fish.

2. The percentage by weight of usable-size fish must be between 40 and 85 percent of the pond's carrying capacity, the most desirable range being 60 to 85.

3. At least 35 percent and preferably 60 to 70 percent of the total weight of bluegills should be of usable size.

These criteria are based on a large number of experiments.

Swingle (1950) gives a method of calculating stocking rates according to carrying capacities of ponds and the results to be expected approximately 1 year after the bass are planted. Swingle has shown that the expected average mortality of bass and bluegills during the first year is 30 and 25 percent, respectively. The bass can be expected to average 1 pound and the bluegills 0.25 pound within 1 year. In calculating stocking rates to provide a given ratio of predators to nonpredators for a given carrying capacity, the mortality of bass is considered; but as the bluegills reproduce the first summer, their mortality is ignored. However, in calculating the poundage of usable-size fish to be produced in 1 year, the mortality of both species must be considered.

The theoretical expectations from different types of stocking were closely approached by actual results. Therefore, Swingle's methods for calculating stocking rates can be accepted for practical utilization as long as we keep in mind that results can be affected by factors other than stocking rates and carrying capacities. The amount of cover that may interfere with predation is probably the factor most commonly found, and certainly it is of much importance in unfertilized ponds.

According to the methods of Swingle, the planting rate of 100 bass and 1,000 bluegills per acre would be expected to provide a satisfactory stocking for ponds with a carrying capacity of 320 pounds (70 of bass and 250 of bluegills).

In the field it has been observed that many unfertilized ponds stocked with 100 bass and 1,000 bluegills provide satisfactory angling during the last half of the second summer and during the first half of the third summer. Some unfertilized ponds provide satisfactory fishing throughout the third summer and during the early spring months of the fourth, after which the population usually becomes static. The data in table 4 support these observations. This suggests that the stocking rate of 100 bass and 1,000 bluegills is too heavy for most unfertilized ponds, as they usually do not provide fishes of a suitable size for harvesting until the last half of their second summer. Weed growth that interferes with predation undoubtedly must be considered along with overstocking as a factor that accelerates the progression of the heavier bluegill to bass ratio. When properly

fertilized, such static ponds normally attain an ideal balance and continue to provide an excellent harvest of fishes indefinitely. The stocking of 100 bass and 1,000 bluegills per acre appears adequate for approximately 25 percent of the unfertilized ponds and too heavy for approximately 51 percent of them (table 2). As the stocking of 100 bass and 1,000 bluegills is adequate for a pond with a carrying capacity of 320 pounds, it would appear that we are warranted in stating that approximately 25 percent of our unfertilized ponds have a carrying capacity of approximately 320 pounds per acre, and that 51 percent or more have a carrying capacity of less than this amount. Undoubtedly, abnormal mortalities of the original stock affected the results in many of the remaining ponds as well as in some of the two groups just mentioned.

The sampling of fish populations from ponds experimentally stocked by the Division of Game and Fish in Kentucky supports our belief that carrying capacity is an important factor to consider in obtaining the correct amount of predation in a given water. The stocking of 30 adult bluegills in the fall or spring, followed by 100 advanced bass fry per acre in May or June, consistently produced populations with a ratio of 1 pound of bass to approximately 3 pounds of bluegills. This statement is based on observation of 17 ponds from 2 to 5 years of age. That the ratio in pounds of bluegills to bass was at least, or more than, 2.7 to 1 was demonstrated by the fact that the bluegill population consisted of all size groups and supported a bass population making satisfactory growth. If the ratio had been less than 2.7 to 1, the predator populations would have been on the decline, characterized by numerous small bass, bass in poor condition, and practically no escapement of small bluegills (Swingle 1950). Actually the bass from the original stocking grew to 1 pound in a year and often averaged 1.25 pounds each. The carrying capacity of these ponds can be estimated roughly from the data available. Assuming a mortality of 30 percent, we can expect the development of approximately 70 pounds of bass at an average of 1 pound each. At a ratio of 1 pound of bass to 3 of bluegills, the total estimated weight of both bass and bluegills would be 280 pounds per acre.

In an unpublished report,[2/] Clark says that the rate of 50 bass and 500 bluegills per acre proved unsatisfactory for several thousand unfertilized ponds in Kentucky. This rate of stocking theoretically provides for a pond with a carrying capacity of 160 pounds (35 of bass and 125 of bluegills), which is believed to be considerably below the carrying capacity of many unfertilized ponds in the southeastern United States, and which is probably below the carrying capacity of large numbers of ponds in Kentucky. In the limited number of ponds with which we have had experience, the stocking of 50 bass and 500 bluegills per acre has resulted in large numbers of intermediate-size bluegills (static ponds) the second and following summers. Small unfertilized ponds ordinarily have a high percentage of their bottoms covered with weeds, a condition which reduces predation. Furthermore, the weight of bass that can be carried is so limited that survival from the original planting will tie up the predator weight in large individuals too few in number to maintain an ideal balance.

Static populations obviously have a bass-bluegill ratio of more than 1 to 5--probably between 1 to 6 and 1 to 10. As unfertilized ponds in ideal balance the second year tend to become heavier and heavier on bluegills and become static with age (table 4), it would be more reasonable to stock these ponds to provide a ratio nearer 1 to 3. This would give an opportunity for the ponds to produce excellent fishing for a longer period of years, depending on the amount of cover, before they become too heavy on the nonpredators. This would allow also for small quantities of "wild" fishes, such as green and longear sunfishes (L. cyanellus and L. megalotis), which are able by one method or another to enter some of the ponds before bass predation is effective.

Our observations strongly suggest the necessity of using approximately 100 bass (70 percent survival) per acre for unfertilized waters in order to obtain

[2/] Clark, M. E. Kentucky's farm pond program. Unpublished report. Division of Game and Fish, Frankfort, Kentucky. 1950.

TABLE 4.--Analysis of 289 problem ponds: ponds of known age grouped according to balance and fertilization

Balance	Fertilization	Age when sampled: 2 - 3 Summers[1/] Number	2 - 3 Summers Percent	4 - 5 Summers Number	4 - 5 Summers Percent	6 - 20 Summers Number	6 - 20 Summers Percent
Bass heavy	Fertilized	2	3.4	1	2.6	0	0.0
Bass heavy	Unfertilized	10	9.0	6	11.5	3	11.1
Ideal	Fertilized	39	66.1	26	68.4	1	50.0
Ideal	Unfertilized	32	28.8	10	19.2	4	14.8
Static	Fertilized	11	18.6	8	21.0	1	50.0
Static	Unfertilized	47	42.3	26	50.0	19	70.3
Unbalanced	Fertilized	7	11.8	3	7.9	0	0.0
Unbalanced	Unfertilized	22	19.8	10	19.2	1	3.7
Totals	Fertilized	59	99.9	38	99.9	2	99.9
	Unfertilized	111	99.9	52	99.9	27	99.9

[1/]Number of summers the ponds have been stocked with bass. The general practice is to plant bluegills in late summer or during the fall prior to spring planting of bass.

predation adequate to prevent the establishment of a dominant intermediate-size group in the bluegill population. Field observations suggested this, particularly where the stocking was considerably below the carrying capacity of the pond and the total number of bass used was well below 100 per acre. The minimum number of bluegills that can be used with 100 bass and satisfy the 3 to 1 ratio is 840 (table 5). This would provide a stocking rate suitable for waters with a carrying capacity of 280 pounds per acre. It would provide within 1 year approximately 227 pounds of usable-size fish per acre, representing 81 percent of the 280-pound carrying capacity. This rate of stocking could be used on ponds having carrying capacities from 280 to 330 pounds and still satisfy all requirements to obtain balanced ponds. For ponds with a carrying capacity below 280 pounds, the number of bass should be reduced accordingly in order to provide for the 1 to 3 ratio (table 5). It is our opinion that small unfertilized fish ponds with carrying capacities of less than about 240 pounds per acre cannot be stocked with the expectation of a high degree of success. This appears to be related to inadequate bass predation to prevent the overcrowding of bluegills. This inadequate predation appears to be due not only to the small number of bass that must be planted to obtain the 1 to 3 ratio, but also to the high percentage of the pond bottom that is covered by weeds. As large numbers of our unfertilized ponds have carrying capacities well under 240 pounds per acre, much more importance should be given this phase of the problem at our experimental stations.

THE WEED PROBLEM

Our observations suggest that not much more than 10 percent of the pond bottom should be covered with vegetation (the Nymphaeaceae not considered) if overcrowding of bluegills is to be prevented. We must admit that any evaluation of the relation of cover to predation is difficult because of the great variety of plant forms and the density of growth under different ecologic conditions. As weeds normally grow to a depth of approximately 6 feet in unfertilized waters, we can easily suggest the approximate minimum requirements for unfertilized ponds in which successful stocking can be anticipated. As the minimum of shallow area

TABLE 5.--The relative number of bass and bluegills necessary to provide ratios of 1 to 3, 1 to 4, and 1 to 5 at different carrying capacities

Pounds carrying capacity	Ratio of 1 to 3 Bass - Bluegill	Ratio of 1 to 4 Bass - Bluegill	Ratio of 1 to 5 Bass - Bluegill
100	36 - 300	28 - 320	24 - 332
140	50 - 420	40 - 448	33 - 460
160	57 - 480	46 - 496	38 - 532
200	71 - 600	57 - 640	47 - 660
240	1/ 86 - 720	68 - 768	57 - 800
260	93 - 780	74 - 832	61 - 860
280	100 - 840	80 - 896	66 - 932
300	107 - 900	86 - 960	71 - 1,000
320	114 - 960	91 - 1,024	76 - 1,066
340	121 - 1,020	97 - 1,088	81 - 1,132
360	128 - 1,080	103 - 1,152	86 - 1,200
380	135 - 1,140	108 - 1,216	90 - 1,266
400	143 - 1,200	114 - 1,280	95 - 1,332
420	150 - 1,260	121 - 1,360	100 - 1,400

1/ The proposed usable rates are underscored.

in relation to the total would occur in circular ponds, in table 6 are listed the percentages of circular areas extending 1.5, 6, 10, and 24 feet, respectively, from the pond periphery in various sizes of ponds.

The 1.5- and 6-foot widths were chosen because of the minimum slope of 1 to 1 and 4 to 1 that engineering specifications will permit in clay and sand soils, respectively. As weeds can be controlled in depths below about 1.5 feet in properly fertilized ponds, areas delineated by these widths (1.5 feet in clay soils and 6 feet in sand soils) on the periphery of circular ponds, would be the areas where weeds would be uncontrolled. The 6- and 24-foot widths represent the minimum widths possible in clay and sand soils, respectively, within the 6-foot contour, or areas where weeds would be expected to occur in unfertilized ponds. The percentage of area in the outer 10 feet of a circle is included for comparison because it is believed to be a more realistic figure for most ponds where

TABLE 6.--Comparison of circular areas extending various distances from the periphery in ponds of different sizes

Area acres	Percent area outer 1.5 feet	Percent area outer 6 feet	Percent area outer 10 feet	Percent area outer 24 feet
0.25	5	19	31	65
.30	-	18	29	60
.50	-	14	22	49
.75	-	11	18	41
1.00	-	10	16	36
2.00	-	-	12	27
4.00	-	-	-	19
8.00	-	-	-	10

care is taken to excavate and slope the edges properly to obtain the maximum control of weeds.

In sand soils where the slope is 4 to 1, it would be necessary to have a circular area of at least an acre in order to have as little as 10 percent of the area under 18 inches in depth, where weeds cannot be controlled by fertilization.

The smallest circle possible in which 10 percent of its area is in the outer 6 feet of the circle, is 1 acre in clay soils or 8 acres in sand soils. It is not likely that many unfertilized ponds in clay soils will be constructed with the slope less than an average width of 10 feet within the 6-foot contour. In the latter case, it would necessitate a circular area of 2 acres to obtain an area of 12 percent less than 6 feet in depth. It is our belief that little degree of success can be expected from the stocking of unfertilized ponds with areas less than about 2 acres in clay soils or 8 acres in sand soils, unless special care is taken in sloping the outer edges of the bottom or unless some form of weed control is used. It is fortunate for the angler that large numbers of small ponds are used by farm animals that provide some weed control by trampling and the consequent settling of silt particles on the leaves. In many ponds used by farm animals the turbidity caused by phytoplankton is adequate to control weeds during the hotter months of the growing season.

DISCUSSION

In discussing the problems of stocking rates and weeds, it would appear that we are not aware of the many difficulties that may arise from ponds with faulty location or construction, unwanted "wild" fishes, and inadequate harvesting. It is true that all these factors and many more are closely related to the production of satisfactory angling. It is our belief that the proper balance of predators and nonpredators of desirable species is the factor that permits a satisfactory harvest by the hook-and-line method. Furthermore, the stocking rate in relation to carrying capacity and the weeds that reduce predation are the two primary factors that permit or prevent the development and maintenance of a fish population in ideal balance.

It is our belief that, to obtain and maintain a properly balanced fish population, about 90 percent of the pond bottom should be free of vegetation. This will limit the size of unfertilized ponds from which results can be expected to approximately 1 to 2 acres in clay soils or 8 acres in sand soils, with many variations, according to the slope of the bottom and areas that are less than 6 feet in depth.

Unfertilized ponds of less than an acre and having a carrying capacity of less than 240 pounds per acre would appear difficult to manage because of the small number of bass available for predation when stocked for the 1 to 3 weight ratio of bass to bluegills. For example, an acre pond with a carrying capacity of 160 pounds, stocked with the maximum number of bass, would permit a stocking rate of 57 bass and 480 bluegills. After a year, 70 percent, or 40 bass, could be expected to have survived and provided a weight of 40 pounds. As 40 pounds of bass is the maximum that the pond will support and still stay in balance, and as many of the original bass can be expected to grow to 2 or more pounds, it would appear that the number of bass would be so limited that there would be inadequate predation unless there was selective fishing for large bass. In other words, the maximum weight of bass that can be carried is so small that a few large bass tie up most of the weight and thus limit the number of bass available for predation. Invariably, small unfertilized ponds have a few large bass and an overcrowded bluegill population by the time the pond has attained 3 years of age. Fertilized ponds less than about 0.3 acre in area present similar difficulties. In the latter case, the fishes usually grow faster, have shorter lives, and are fished more intensively, thus receiving the melioration that permits more successful management. It appears obvious that if we are to manage small unfertilized ponds successfully, we shall have to consider other fishes, particularly predators, in addition to the bass and bluegill combination. Furthermore, economical and practical

methods of weed control must be discovered if successful management is to be attained with the bass and bluegill combination.

If we are to stock ponds more closely in accordance with the needs dictated by carrying capacities, it will be necessary to have field men (agricultural extension agents, soil conservation agents, fishery biologists, or others) with a knowledge of the carrying capacities of ponds in specific areas and a knowledge of how individual pond conditions may affect carrying capacities and balance, so that suitable stocking rates may be used. Table 5 explores the relation of stocking rates to carrying capacities, and the underscored rates appear to meet stocking requirements. Theoretically, the stocking rates meet the requirements of ponds that have carrying capacities of 40 to 50 additional pounds.

The use of any uniform stocking rate in unfertilized ponds can be expected to create a large number of unsuccessful fishing ponds, since unfertilized ponds do not appear to have the facilities to transform their fish populations into ideal balance, as do fertilized ponds.

Properly fertilized ponds have less range in their carrying capacities and come into ideal balance in time if stocking conditions have not been completely appropriate, provided that adequate bass survive from the initial introduction to provide the necessary predation.

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From the U. S. Fish-Cultural Station at Neosho, Missouri, comes the suggestion that the most convenient method of hauling fish about the station pond battery and from ponds to holding shed, is by means of a tarpaulin placed inside the bed of a pick-up truck and filled with water. A. C. Balch, superintendent, reports that this use of a tarpaulin provides more surface area to water for aeration and enables the fish-culturist to load the fish from the ground without injury. When the fish are to be unloaded, the tail gate of the truck is lowered and the edge of the tarpaulin is let down--and the fish go down a chute without requiring further handling in a dip net. As it has been found that more fish can be transferred safely from one location to another in a tarpaulin than formerly could be hauled in tanks or barrels, a canvas is being stitched to fit the bed of the station pick-up truck and will be kept solely for this purpose.

THE COEFFICIENT OF CONDITION OF BROOK, BROWN, AND RAINBOW TROUT IN THE PIGEON RIVER, OTSEGO COUNTY, MICHIGAN

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THE PIGEON River is located in the north-central portion of the lower peninsula of Michigan. It flows for about 60 miles in a northerly direction through wooded terrain to empty indirectly into Lake Huron. Approximately halfway upstream from the mouth, a 5-mile portion of the river has been set aside as a trout research area. From April 1949 to October 1950, data on the length and weight of both hatchery trout and naturally spawned trout have been obtained in conjunction with other studies in progress. The present paper deals with the change in condition of the hatchery fish after planting and a comparison of these data with the condition of native fish.

The coefficient of conditions (R) as used in this study was calculated for each fish on the basis of the formula:

$$R = \frac{W \times 10}{L^3}$$

where W = weight in grams,
and L = total length in inches.

The conversion factor for use between the English C (total length in inches, weight in pounds) and R (total length in inches, weight in grams) is as follows:

$$R \times 22.038 = C.$$

Conversion factors between R and K (standard length in millimeters and weight in grams) are not given because of the curvilinear relationship existing between standard length and total length in brook trout in Michigan. According to data taken from 1,957 brook trout ranging in standard length from 40 millimeters to 360 millimeters, this relationship was established as follows:

$$\text{Total length} = 1.4137 \text{ standard length}^{0.964}, \text{ or}$$

$$\text{Log total length} = 0.15037 + (0.964 \log \text{standard length}).$$

The relationship between R and K must be calculated for each fish, from the data given above.

The selection of units of measurement is largely one of convenience. Measuring boards used are calibrated in inches and tenths of inches. The Chatillon dietary scales used in weighing the fish are calibrated in grams. With the small size of the fish generally encountered in our work, the gram seems to be the most appropriate unit of weight, although a scale graduated in hundredths of a pound would be equally as good.

The problems involved in the standardization of fish measurements and the corresponding calculation of condition factors have been well summarized by Hile (1948). Until such standardization is adopted by fishery investigators in general, a

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Contribution from the Michigan Institute for Fisheries Research.

comparison of coefficients of condition between different workers will remain difficult. When the relationship between different fish measurements such as standard length and total length is nonlinear, even trends in the change of condition with an increase in size may be reversed by the selection of different length measurements. Compare C and K of largemouth black bass cited by Beckman (1948). Factors for conversion of standard, fork, and total lengths of fish, when given, are useful in the computation of comparable data, but authors do not always agree with one another as to the coefficients, even for the same species of fish. For example, compare the conversion factors between standard and total lengths for both brook trout and brown trout given by Carlander and Smith (1945) with those of the New York State Hatcheries (mimeographed). These coefficients, as well as those for many other species, have been recently compiled by Carlander (1950).

The apparent confusion in the methodology of computing condition factors of fish does not invalidate a study of the changes of conditions due to season, sex, and other factors when the same index of condition is used. Authenticated changes in condition of fish of a general nature should be comparable even though the actual values for the coefficients differ because of different units of measurement used. However, slight differences in these condition factors should be viewed with skepticism until their nature is fully understood and their validity is established through repeated observations.

SOURCES OF VARIATION IN CONDITION FACTOR

The interpretation of differences in the coefficient of condition among groups of fish depends to a large extent upon the recognition of the sources and extent of variation. Such a variation is shown among different species of trout reared at separate hatcheries and also from samples of wild brook and brown trout taken from the Pigeon River (table 1). Small numbers of fish therefore may not be representative of the condition of the group from which they came, owing to improper or inadequate sampling methods. The use of statistical measures of central tendency and their accompanying measures of reliability is recommended for studies dealing with coefficients of condition.

Another source of variation found in many species of fish is a normal change in the condition factor as the fish increases in size. This change in condition is associated with a change in form of the fish as it increases in size, and is directly reflected in the length-weight relationship. If form and specific gravity remained constant as the fish grew in length, the length-weight relationship would be expressed by the formula:

$$W = CL^3, \text{ the well-known cube law.}$$

Since the length-weight relationship of most species of fish has been found to differ slightly from the cube law, the more general formula:

$$W = CL^n$$

has been used to express this relationship. Because the coefficient of condition is based on the cube law, values of n in the more general formula indicate the direction and degree of change of the coefficient of condition of a species with an increase in size. For some fish, such as the bluegill and yellow perch, the condition factor increases slightly as the fish grow in length (Beckman 1948). For both the brook and the brown trout populations in the Pigeon River, this trend is reversed; the fish become relatively lighter as they increase in length. This change may easily be seen by an examination of the length-weight relationship of the two species (figures 1 and 2). However, variations in conditions of this nature are usually slight and do not invalidate the comparison of the coefficient of condition of fish of different sizes to any extent.

A marked seasonal change in condition was observed for both native brook and brown trout in the Pigeon River. In this stream, native rainbow trout at the present time are too rare to afford opportunity for comparative study. Collections

TABLE 1.--Variation in condition of hatchery trout from Oden Hatchery and Wolverine Rearing Ponds, and of wild brook and brown trout from the Pigeon River, Michigan

Species	Locality and date	Number of fish in sample	Size range	Coefficient of condition (R)			
				Range	Mean	Standard deviation	Standard error of mean
			(Inches)				
Brook	Oden Hatchery April 27, 1949	100	6.8- 9.9	1.43-2.01	1.72	0.12	0.012
Brown	Wolverine Rearing Ponds April 27, 1949	100	8.1-12.5	1.29-1.92	1.56	0.13	0.013
Rainbow	Wolverine Rearing Ponds April 27, 1949	100	6.8-12.8	1.12-1.96	1.61	0.15	0.015
Brook (native)	Pigeon River May 13 - June 21, 1949	100	6.9-10.5	1.40-2.11	1.65	0.15	0.015
Brown (native)	Pigeon River May 1 - August 2, 1949	100	6.9-18.5	1.22-2.01	1.62	0.14	0.014

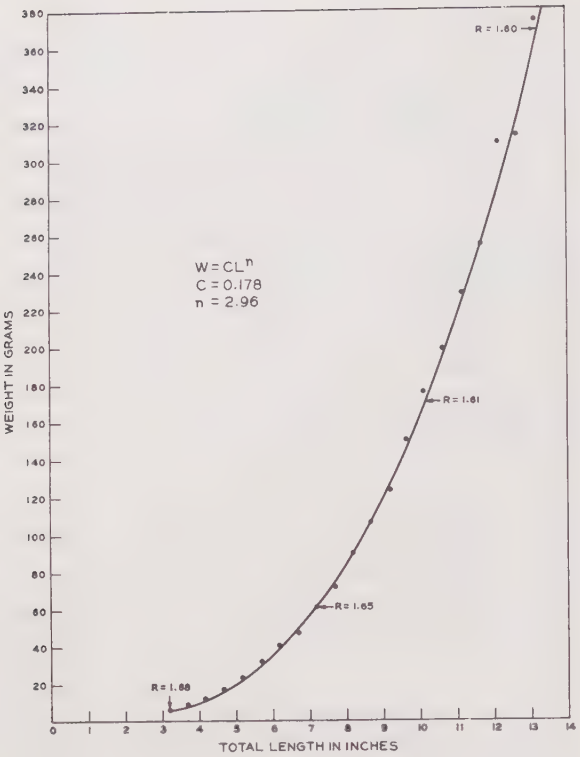

FIGURE 1.--Length-weight relationship of native brown trout in the Pigeon River. Electric shocker and angler collections, April 1949 to June 1950. Line fitted mathematically from data on 1,003 specimens.

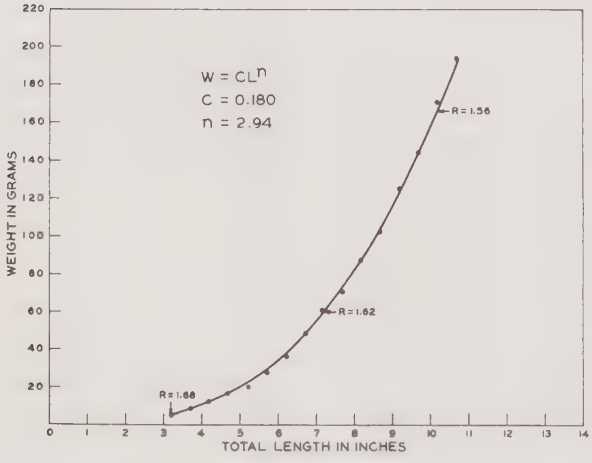

FIGURE 2.--Length-weight relationship of native brook trout in the Pigeon River. Electric shocker and angler collections, April 1949 to June 1950. Line fitted mathematically from data on 1,997 specimens.

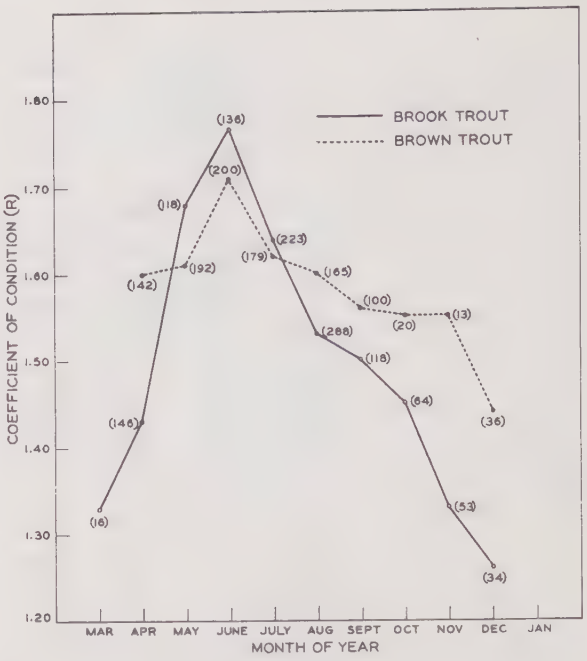
BROOK TROUT
BROWN TROUT
COEFFICIENT OF CONDITION (R)
MONTH OF YEAR
MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN
(16) (146) (18) (136) (223) (288) (118) (64) (53) (34)
(142) (192) (200) (179) (165) (100) (20) (13) (36)

FIGURE 3.--Seasonal variation in condition (R) of native brook trout and native brown trout in the Pigeon River. In parentheses is given the number of specimens upon which the average condition factor is based. Brown trout collected by electric shocker and anglers; brook trout from electric shocker collections, only; data for 1949 and 1950 combined.

were made with an electric shocker in all months of the year except January and February, at which time ice conditions made fish-collecting impossible. For both brook and brown trout the coefficient of condition was low during winter and early spring, rose rapidly to a peak in June, and subsequently declined rather uniformly to the winter low (figure 3). Brown trout apparently do not fluctuate so much in condition throughout the year as brook trout in the same stream. Both species exhibit in the late fall a drop in condition which probably is coincident with spawning, although the coefficient of condition immediately prior to spawning is less than the peak condition in June.

The condition of the native fish caught by anglers during the trout season (figure 4) follows very closely the trend just described for collections made with the

electric shocker. To what extent the drop in condition in July and August is due to a rise in water temperature to a point generally considered too warm for trout, is largely unknown. Although water temperatures decreased again in late August and September, the coefficient of condition of the fish continued to decline.

In an earlier study of the brook trout in streams of New York (Hazzard 1932), it was indicated that the fish were heaviest at the spawning season, losing weight thereafter and not recovering condition until after several weeks of feeding in the spring. A summary of seasonal changes in condition of the brook trout in Hunt Creek, Michigan (Shetter, unpublished), revealed that the peak of condition was reached during May. There was a decline in condition factor during July and August and an increase again during September and October to nearly the same condition as in May. A seasonal decline in the condition of the fish before the spawning season was observed for the whitefish of Lake Erie (Van Oosten and Hile 1949) and for the kiyi of Lake Michigan (Deason and Hile 1947). More information on the seasonal changes in condition of trout in different localities is desirable. Also, information is needed concerning such factors as food supply, water temperatures, growth rate, and population density, with reference to their effects on the condition of fish.

VARIATION IN CONDITION OF HATCHERY FISH

Extensive plantings of hatchery-reared brook, brown, and rainbow trout were made in the Pigeon River during the open trout

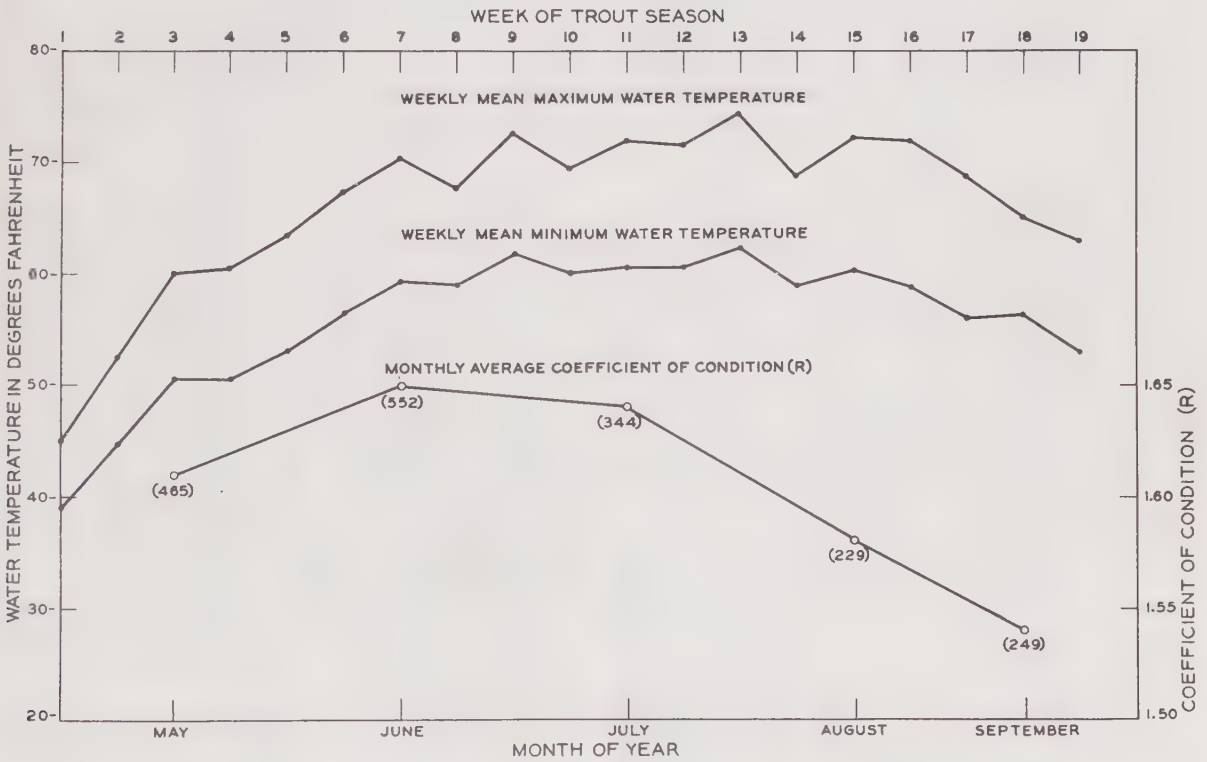

FIGURE 4.--Seasonal variation in condition (R) of native trout (brook, brown, and rainbow combined) caught by anglers in the Pigeon River during the 1949 and 1950 trout seasons, compared with stream water temperatures.

seasons of 1949 and 1950 (table 2). Recoveries from a little more than 40 percent of these trout furnished data on the changes in condition after planting. A permit system of angling required fishermen to present their catch at a checking station, where each hatchery fish recovered was measured and weighed. Individual records were assured by marking each fish with a jaw-tag before planting. For a few plantings in 1950, half of each planting was fin-clipped, the other half jaw-tagged.

Brook trout were somewhat heavier at the time of marking than either the browns or rainbows (tables 2 and 3). The difference in condition was probably due to their origin from different rearing stations rather than a difference per se between the species, as native brook and brown trout from the Pigeon River are nearly identical as to condition at any given time of the year (table 4). Oden Hatchery derives its water supply from numerous springs; the temperature seldom rises above 50° to 55° F. The Wolverine Rearing Station gets its water from the Sturgeon River, where water temperatures frequently go above 70° F. during the summer.

The hatchery brook trout were considerably heavier at the time of marking than the native brook trout but very quickly lost condition (table 3). The hatchery brown and rainbow trout changed very little after marking. It is believed that much of the initial loss in condition of brook trout occurred during the 1- to 2-day period of enforced fasting caused by their retention in live cages before planting. This observation is substantiated by the data in table 3. Notice that the condition of the brook trout recovered on the same day they were planted was considerably less than when they were marked, and that little or no further loss occurred during subsequent days in the stream. No such loss was observed in the brown and rainbow trout; however, they usually were marked after the brook trout and the period in live cages was less.

Changes in condition subsequent to the first week after planting were slight for all species (table 3). Apparently the hatchery fish were able to adjust themselves to stream conditions and to compete successfully with the native fish for food. These observations are apparently contradictory to the conclusions of Klak (1941) as a result of similar studies made in Virginia.

Most of the plantings of hatchery trout were numerous enough to more than double the population of legal-sized fish in the stream at least temporarily. The experimental area of the Pigeon River has been divided into four fishing sections, designated as A, B, C, and D. The plantings were made in the two center sections; judging from the fish that were recaptured either by angling or by the electric shocker, it appears that the hatchery trout did not move to a great extent from the vicinity in which they were planted. Despite this sudden increase in competition for food and space, no corresponding decrease in the condition of wild fish was observed; the condition of the wild fish taken in Sections A and D was the same as that of fish taken in Sections B and C (table 4). This suggests that the supply of food in the stream was more than adequate for the native population alone.

Seasonal changes in condition of hatchery trout, corresponding to those for native populations in the Pigeon River, were not observed except perhaps as the slight loss in condition of the hatchery trout recovered after a long interval could be interpreted as a seasonal decline. The wild trout caught by anglers showed a decline in condition as the season progressed past June. The bulk of the hatchery trout recaptured after an interval of more than a week after planting were taken in the latter part of the season. The loss observed for these fish might be interpreted, therefore, as being similar to that observed for the wild trout.

A comparison of hatchery fish at different times during the season reveals that, in general, their condition remains relatively high from April to August--according to data from the fish planted in the Pigeon River (table 2). Although the brook trout planted in June 1950 were in poor condition as compared with the

TABLE 2.--Hatchery trout (brook trout from the Oden Hatchery, brown and rainbow trout from the Wolverine Rearing Ponds) planted in 2.3 miles of the Pigeon River[1/] during the seasons of 1949 and 1950

Date of planting	Brook trout			Brown trout			Rainbow trout		
	Number	Size range (Inches)	Coefficient of condition (R)	Number	Size range (Inches)	Coefficient of condition (R)	Number	Size range (Inches)	Coefficient of condition (R)
April 28, 1949	300	6.8-10.2	1.73	300	7.5-12.5	1.58	300	7.2-14.6	1.65
May 25, 1949	300	6.9- 9.3	1.80	300	7.0-10.7	1.52	300	7.4-12.6	1.66
June 29, 1949	300	7.2-11.0	1.86	300	7.1-13.2	1.60	300	7.0- 9.9	1.58
July 27, 1949	300	7.0-10.6	1.94	300	7.1-11.1	1.69	300	7.0-10.5	1.63
August 17, 1949	300	7.0-10.8	1.87	300	7.5-11.7	1.66	300	7.0-11.8	1.60
1949 total planted	1,500	--	--	1,500	--	--	1,500	--	--
Percent of recovery in 1949	40.0	--	--	25.6	--	--	44.7	--	--
Percent of recovery in 1950	0.0	--	--	2.2	--	--	2.3	--	--
April 26, 1950	1,000	7.0-11.1	1.90	--	--	--	1,000	7.0-11.5	1.58
June 1, 1950	1,000	6.9-11.1	1.60	--	--	--	1,000	7.0-10.2	1.52
August 8, 1950	500	7.0-11.0	1.78	--	--	--	--	--	--
1950 total planted	2,500	--	--	--	--	--	2,000	--	--
Percent of recovery in 1950	47.4	--	--	--	--	--	52.5	--	--

[1/] Minimum legal size for trout in this stream is 7 inches.

TABLE 3.--Changes in condition of hatchery trout after planting in the Pigeon River, Michigan, during 1949

/All data from individual tagged fish; in parentheses is the standard error of the mean for that sample./

Time of sampling	Brook trout			Brown trout			Rainbow trout		
		Mean condition factor (R)			Mean condition factor (R)			Mean condition factor (R)	
	Number	When marked	At recovery	Number	When marked	At recovery	Number	When marked	At recovery
Random sample of entire planting; 100 from each of 5 plantings of 300. Condition at time of marking.	500	1.81 (0.007)	--	500	1.59 (0.006)	--	500	1.61 (0.006)	--
Fish recovered by anglers the same day they were planted	61	1.78	1.66	14	1.66	1.65	40	1.60	1.55
Fish recovered the second day	41	1.75	1.63	18	1.63	1.57	22	1.61	1.52
Fish recovered the third day	24	1.77	1.61	6	1.60	1.55	17	1.63	1.54
Fish recovered the fourth day	48	1.81	1.64	18	1.61	1.54	40	1.57	1.49
Fish recovered the fifth day	54	1.77	1.65	18	1.64	1.58	39	1.61	1.58
Fish recovered the sixth day	19	1.82	1.61	10	1.70	1.56	16	1.50	1.48
Fish recovered the seventh day	32	1.62	1.65	8	1.62	1.61	17	1.64	1.61
Total of all fish recovered first 7 days	279	1.79	1.64 (0.008)	92	1.64	1.54 (0.015)	191	1.59	1.57 (0.009)
Total of all fish recovered after 7 days of the season (1949)	223	1.80	1.58 (0.009)	241	1.63	1.51 (0.010)	350	1.57	1.48 (0.009)
Total of all fish recovered during the following fishing season (1950)	0	--	--	25	1.65	1.50	31	1.56	1.49

TABLE 4.--Coefficient of condition (R) of native brook trout and brown trout caught by anglers in the Pigeon River during 1949 and 1950

/Fishing sections B and C were stocked with hatchery trout; sections A and D were not./

Species	Fishing section	Number of fish in sample	Average length	Coefficient of condition (R)
			(Inches)	
Brook	A	163	7.7	1.59
	D	524	7.6	1.63
	A + D	687	7.6	1.62
	B	251	7.8	1.64
	C	452	7.6	1.64
	B + C	703	7.7	1.64
Brown	A	39	8.4	1.61
	D	86	9.0	1.59
	A + D	125	8.8	1.60
	B	131	8.6	1.62
	C	129	8.4	1.61
	B + C	260	8.5	1.61

other brook trout planted, they were about average for all the native trout caught by anglers from the Pigeon River. They also did not lose in condition nearly so much as did the other hatchery brook trout.

During both seasons of stocking, the hatchery plantings were equally divided between "spot" type and "scatter" type to determine the relative merits of the two methods. Recoveries from these groups were about equal and were tallied separately. No difference could be seen in the average condition at recovery of the fish planted by the two methods (table 5), although one might expect that the increased competition for food and space for the spot-planted trout would result in a lower condition factor for such fish.

During 1950, because of a temporary shortage of tags for marking hatchery trout, half of each planting made in June and August were fin-clipped and the other half were jaw-tagged. At the time of marking, alternate groups of fish were taken at random from the hatchery stock to insure no bias (in the selection of fish to be either jaw-tagged or fin-clipped) that might affect the average size of the fish or their condition. Also, equal numbers of tagged and fin-clipped trout were combined in the hatchery holding tanks and planted as a unit, either as a spot plant or as a scatter plant.

From these plantings, fin-clipped trout were much more numerous than the tagged trout among the hatchery fish recovered by anglers; this was true for both brook trout and rainbow trout in four different plantings in June and for the brook trout in one of two plantings in August. However, the condition factor of the recovered trout was not different between fish that had been fin-clipped and those that had been jaw-tagged (table 6).

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Messrs. Gerald Myers, Wayne Tody, Howard Gowing, Robert Ellis, John Claridge, Donald Tesman, and Wilbert Wagner for help in obtaining the data upon which this paper is based.

TABLE 5.--Comparison of the coefficient of condition (R) at time of recovery between spot-planted and scatter-planted hatchery trout in the Pigeon River, Michigan.

/Numbers in parentheses are size of samples upon which calculations are based./

Date of planting	Brook trout		Brown trout		Rainbow trout	
	Spot	Scatter	Spot	Scatter	Spot	Scatter
April 28, 1949	1.63 (90)	1.64 (75)	1.61 (59)	1.61 (108)	1.61 (91)	1.59 (76)
May 25, 1949	1.58 (68)	1.57 (45)	1.45 (55)	1.46 (39)	1.51 (89)	1.52 (75)
June 29, 1949	1.56 (15)	1.59 (18)	1.43 (31)	1.38 (22)	1.37 (35)	1.36 (21)
July 27, 1949	1.57 (30)	1.53 (18)	1.50 (21)	1.44 (7)	1.39 (46)	1.39 (24)
August 17, 1949	1.66 (78)	1.60 (74)	1.59 (37)	1.60 (8)	1.57 (54)	1.53 (30)
April 26, 1950	1.60 (160)	1.56 (145)	--	--	1.55 (162)	1.55 (130)
June 1, 1950	1.51 (121)	1.50 (93)	--	--	1.48 (120)	1.46 (96)
Total	1.59 (562)	1.57 (468)	1.52 (203)	1.54 (184)	1.52 (597)	1.51 (452)

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TABLE 6.--A comparison of the average coefficient of condition of tagged and fin-clipped brook and rainbow hatchery trout recovered by anglers in the Pigeon River

Date	Species	Number planted	Condition at planting	Number recovered		Condition at recovery	
				Tagged	Fin-clipped	Tagged	Fin-clipped
June 1, 1950	Brook	250	1.60	123	-	1.51	-
	Brook	250	1.60	-	173	-	1.51
	Brook	250	1.60	96	-	1.49	-
	Brook	250	1.60	-	146	-	1.54
	Total	500	1.60	219	-	1.50	-
		500	1.60	-	319	-	1.52
June 1, 1950	Rainbow	250	1.52	159	-	1.45	-
	Rainbow	250	1.52	-	190	-	1.47
	Rainbow	250	1.52	129	-	1.45	-
	Rainbow	250	1.52	-	201	-	1.47
	Total	500	1.52	288	-	1.45	-
		500	1.52	-	391	-	1.47
August 7, 1950	Brook	125	1.81	76	-	1.65	-
	Brook	125	1.81	-	76	-	1.62
	Brook	125	1.81	71	-	1.66	-
	Brook	125	1.81	-	96	-	1.67
	Total	250	1.81	147	-	1.65	-
		250	1.81	-	172	-	1.64

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LANDLOCKED SILVER SALMON FOR MONTANA WATERS

Like many another inland State, Montana would like very much to develop a landlocked strain of salmon for stocking her waters. Montana has tried several times to take eggs from silver salmon when they have become of size and age to spawn in the fresh water of that State. Experience has demonstrated, however, that the silver salmon are not ready to spawn before January 1--and by the time the ice breaks up in May, the females have either died or absorbed the eggs.

During the past winter the Montana authorities have approached the problem from another angle. On January 14, 1951, Walter M. Allen, State Superintendent of Fisheries, and Fred Beal, Field Superintendent of the State Fish Hatchery at Anaconda, secured some landlocked silver salmon, both male and female, that were ripe and in suitable condition for spawning. The eggs were taken, eyed, and hatched at the Anaconda Station. The Montana Fish and Game Department now has small silver salmon, produced from these eggs, that have never been in salt water. The Department plans to rear these fish until they are ready to reproduce, when they will be taken again for spawning.

STREAM POLLUTION RESULTING FROM THE USE OF ORGANIC INSECTICIDES

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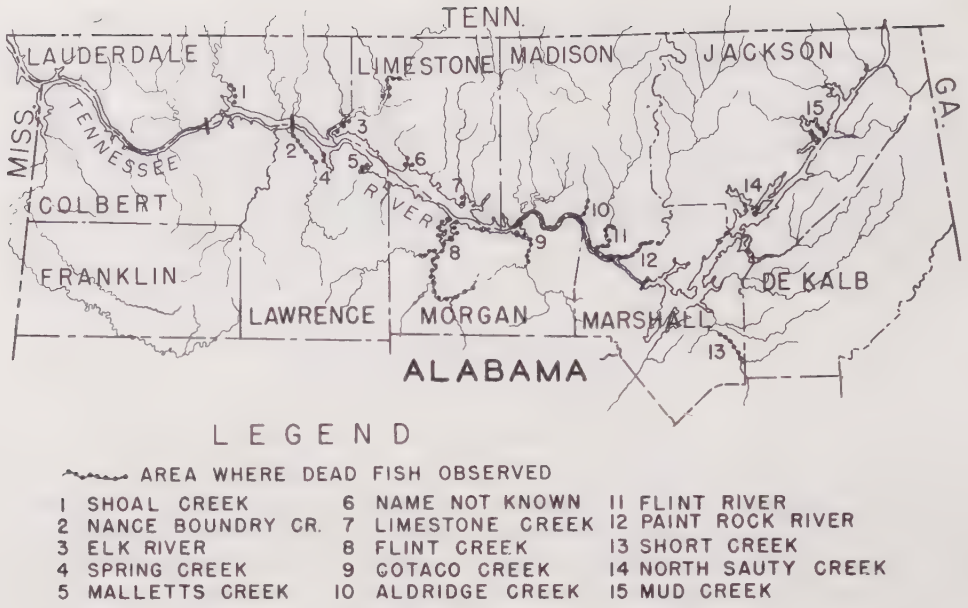
IN AUGUST 1950 there occurred in the important cotton-growing section of northern Alabama 15 known instances of fish kills in streams tributary to the Tennessee River[1/] (see figure). The intensity of these kills ranged from the loss of a few to hundreds of fish and appeared to be associated with dusting operations for the control of cotton insects. Investigations undertaken at that time by members of the Alabama State Board of Health, the Alabama Water Improvement Advisory Commission, and the U. S. Public Health Service indicated the probability that insecticides washed from the soil into the streams by heavy rains were responsible for the wholesale deaths of both game and rough fish species in these streams. Although numerous instances are on record of fish populations in farm ponds being decimated as a result of crop-dusting operations, and of experimental poisoning of fish in streams with insecticides, this is the first instance known to the writers in which the practical application of insecticides has resulted in widespread stream pollution and attendant extensive losses of fish populations.

1/Information concerning the number and distribution of fish kills was obtained, in part, through the courtesy of Lawrence F. Miller and Paul Bryan, Tennessee Valley Authority, Decatur, Alabama.

The authors are Officer in Charge and Basin Biologist, respectively, Southeast Drainage Basins, Division of Water Pollution Control, in the Public Health Service.

In the Tennessee Valley of Alabama, according to reports of county agents, very little organic insecticide was applied for the control of the boll weevil prior to the summer of 1950. The mild winters of 1947-48 and 1948-49, however, favored the overwinter survival and build-up of a dangerous weevil population by the spring of 1950. After losses to the weevil by the end of the 1949 season, the county agents and extension services undertook a selling program to promote the use of insecticides. This stimulated 80 to 95 percent (estimate) of the cotton farmers of the area to turn to the use of organic insecticides in 1950. Figures supplied by the county agents indicate that approximately 26,287,620 pounds were used on 419,500 acres of cotton in eight Tennessee Valley counties of Alabama during the 1950 season (table 1). This represents an average of 63 pounds per acre per season, assuming that the total acreage was treated. It is reported that more would have been applied if it had been available. Most of this insecticide was applied in dust form by ground equipment, although a considerable portion also was applied from the air.

A variety of insecticide formulations was used. The most popular was a dust containing 20 percent of toxaphene, to which 40 percent of sulfur was added in some formulations. Second in popularity were several mixes containing 3 percent of the gamma isomer of benzene hexachloride and varying quantities of the other isomers, 5 percent of DDT, and, in some formulations, 40 percent of sulfur. Late in the season there came into use relatively small amounts of aldrin, applied



Distribution of fish kills resulting from insecticide pollution of streams

primarily as a 2½-percent dust or emulsion. Small amounts of toxaphene also were applied as a 20-percent emulsion, and in a few of the counties minor amounts of calcium arsenate and DDT were used. Throughout the Alabama portion of the Tennessee Valley, toxaphene constituted 61 percent of the total amount of insecticide applied; 34 percent consisted of the benzene hexachloride-DDT mixture; 4 percent contained aldrin; and 1 percent was calcium arsenate or other materials.

Of the insecticides used, excepting aldrin (for which the writers have no information), toxaphene is indicated to be by far the most toxic to fish. Tarzwell (1950) has reported that toxaphene, at a dosage of less than 0.037 p.p.m., applied in solution on ponds, killed many fish species, and that this substance was more toxic to fish than rotenone. He suggested that because toxaphene was such an efficient fish poison, it might be useful as a substitute for rotenone in fish management work.

Linduska and Surber (1948), after studying toxicity tests of various insecticides, stated that toxaphene was considerably more toxic than DDT to fish. They found that in outdoor fish ponds toxaphene at 0.02 p.p.m. (presumably applied as a solution) killed a number of species, but goldfish survived. Young rainbow and brown trout were killed at concentrations as low as 0.005 p.p.m., and the threshold limit for bluegills was 0.01 p.p.m. They also reported benzene hexachloride to be less toxic than DDT. BHC (12 percent gamma isomer) in applications of 0.18 p.p.m. dissolved in fuel oil did not kill bluegills, goldfish, and a number of species of minnows. In aquaria, bluegills tolerated concentrations of 0.45 p.p.m.

Lawrence (1950), in experiments to evaluate the effects of organic insecticides on pondfish, found that adult bluegills, largemouth black bass, and buffalo in earthen ponds were not killed by 1.0 p.p.m. concentration of DDT in the form of wettable powder. In an earthen pond stocked with fathead minnows (Pimephales promelas) and goldfish, a concentration of 0.4 p.p.m. DDT (wettable powder) killed only the recently hatched fathead minnows. Application of 1.6 p.p.m. of additional DDT in the same form, making the total concentration of DDT in the pond equal to 2.0 p.p.m., killed all the fish within 48 hours. In aquaria tests, bluegill fingerlings 2 to 3 inches in length were killed by DDT in concentrations of 0.15 p.p.m.; largemouth black bass fingerlings 3 to 4 inches in length were killed by

TABLE 1.--Cotton acreage and estimate of amount of insecticides used in Tennessee Valley Counties of Alabama, 1950

(Based on data supplied by the county agents)

County	Cotton acreage	Pounds of insecticides applied [1/]	Average number of pounds per acre per season [2/]
Colbert	30,000	1,295,680	43
Jackson	40,000	2,000,000	50
Lauderdale	47,000	2,600,000	55
Lawrence	58,000	3,000,000	52
Limestone	66,000	2,751,000	42
Madison	81,000	6,500,000	80
Marshall	50,000	4,400,000	88
Morgan	47,500	3,740,940	79
Total	419,500	26,287,620	[3/] 63

[1/] In terms of dust formulations, not active ingredients.
[2/] Figures are based on the total acreage grown. Actually the acreage treated one or more times ranged from 80 to 95 percent.
[3/] The quotient of the total pounds of insecticide used divided by the total acreage.

a 0.05 p.p.m. concentration; and goldfish 3 to 4 inches in length were killed by concentrations of 0.2 p.p.m. when the formulation used was 50 percent DDT wettable powder.

Lawrence found that, in aquaria, bluegill and largemouth bass fingerlings were killed by a 0.05 p.p.m. concentration of toxaphene in dust form in 36 hours, and that at this same concentration goldfish became inactive on their sides within 54 hours and were killed in 156 hours. In an earthen pond, a 0.05 p.p.m. concentration of toxaphene did not kill bluegill fingerlings, bass fingerlings, and bait-size goldfish within a 5-week period. When toxaphene dust was applied to a pond at 0.2 p.p.m., all of the above species were killed within 45 hours. This water remained toxic for at least 10 weeks and had not yet lost its toxicity when his paper was written.

Lawrence's aquaria experiments with the 3 percent gamma isomer BHC plus 5 percent DDT dust mixture commonly used in cotton dusting, indicate that bluegills (2 to 4 inches), largemouth black bass (3 to 4 inches), and goldfish (3 to 4 inches) survived a concentration of 0.03 p.p.m. of BHC plus 0.05 p.p.m. of DDT. At a concentration of 0.1 p.p.m. of BHC plus 0.1 p.p.m. of DDT, the bass were killed but bluegills survived; and at a concentration of 0.1 p.p.m. of BHC plus 0.16 p.p.m. of DDT, bluegills also were killed.

It was recommended by Ruffin and Arant (1950) that 20 percent toxaphene dust and the 3-5 BHC-DDT dust mixture be applied to cotton fields at the rate of 10 pounds per acre six or seven times during a normal season. They added, however, that during a season of heavy insect damage or frequent rainfall the rate of application should be increased to 12 to 15 pounds per acre on larger cotton and the number of applications per season should be increased.

The average rates of application per acre per season for each county in the valley, as indicated in table 1, are not out of line with this recommendation. Some farmers, however, are known to have applied the dust in excessive quantities. One reported that he had made 16 applications at 35 to 40 pounds per acre, or a total of 560 to 640 pounds per acre per season.[2/] Several farmers were reported to have applied 200 pounds per acre per season.[3/] Such extreme applications alone, if made on land from which there would be a quick run-off into adjacent streams during a heavy rain, could be

[2/] Information furnished by Tennessee Valley Authority, Decatur, Alabama.

[3/] Information furnished by Loyd Little, County Agent, Madison County, Alabama.

responsible for much of the damage done.

Perhaps the worst fish kill brought to the attention of the authors was that on Flint Creek, a river about 50 miles in length, which lies almost entirely within Morgan County and is impounded at its lower extremity by continuity with Wheeler Reservoir. In the lower 13 miles or more of its length, this river has a mid-channel depth of 6 to about 20 feet depending upon the flood stage. The current in this lower portion is variable, even reversible, owing to water-control practices at Wheeler Dam, but is usually quite slow. The stream is subject to rapid fluctuations in level and to flooding. The fish population in this river probably was totally eradicated. Other severe kills occurred in the Flint River in Madison County and in Short Creek in Marshall County. A résumé of what happened in Flint Creek will serve to describe conditions typical on the entire area.

The extensive use of insecticides was begun in Morgan County early in July. Too frequent local showers beginning in mid-July plagued the farmers and made necessary the application of insecticides at shorter intervals than usual. (The rainfall at Decatur in Morgan County was above average by 2.85 inches in July and by 5.78 inches in August.) No heavy rains occurred, however, until August 1 or 2. This rain resulted in a 6-inch rise in the water level at the Hartselle Water Plant intake, 10.3 miles above the river mouth. On the morning after the rain, a farmer living near the stream, approximately 37 miles above its mouth, observed that fish were acting peculiarly. They appeared "addled" and were swimming around in circles just under the surface. This farmer caught a number of these fish (most of which were carp) and placed them in a spring-fed pool, where most of them recovered. On the afternoon after the rain, a great number of dead fish floated down the stream past this farm. Other observers of poisoned fish on Flint Creek have reported that they behaved in an extremely uncoordinated manner and occasionally threw themselves out of the water to the adjacent riverbank, stranding themselves in the process.

The next heavy rain in the Flint Creek watershed came on August 10, causing a 3-foot rise in the river level at the Hartselle Water Plant intake and an increase in the turbidity of the stream. This was followed by a very heavy fish kill during August 11-14. On August 15 another heavy rain caused a 3-foot rise in water level and an increase in turbidity, but little additional kill appeared, presumably because the population had been depleted. However, from August 16-20, goldfish (a species more resistant than most to poisoning by organic insecticides) which were placed daily in cages in the river at the Hartselle Water Plant intake died within 18 hours. On August 21, the goldfish became affected within 24 hours. No additional data of this nature were obtained.[4/]

On August 18, the situation just described was brought to the attention of the writers. A visit to the area revealed a few fish still dying and hundreds of dead fish of all sizes up to 15 pounds. Rough fishes (carp, buffalo, drum, gizzard shad, and catfish) predominated, but white crappies were killed in exceedingly large numbers. Smaller numbers of dead bass and sunfish were seen. These dead fish also were very abundant in the broad arm of Wheeler Reservoir, which constitutes the mouth of Flint Creek. Affected fish captured for examination showed no visible damage or coating to the skin or gills. The only visible abnormality, other than loss of coordination, was a deep wine color of the gills.

No loss of fish life of such extent had been reported from the area prior to 1950, nor had there been any major change in the watershed except for the application of insecticides for the control of the boll weevil. No source of industrial pollution, which might have been the cause of these kills, is known to exist on the Flint Creek watershed.

The only source of municipal pollution is the city of Hartselle.[5/] During 1948 a survey made by the Bureau of Sanitation of the Alabama State Department of Public Health revealed that the effluent from the sewage treatment plant at Hartselle,

[4/] Unpublished records of Coy Stephenson, Superintendent of the Hartselle, Alabama, Water Treatment Plant.

which enters the creek approximately 31 miles above its mouth, did not affect the chemical condition of Flint Creek. Chemical analyses made of water taken at several points along the creek and at the Hartselle water intake on August 15, 1950,5/ indicated that dissolved oxygen, hydrogen-ion concentration, total alkalinity, and free carbon dioxide were within the normal limits which would permit the existence of fish life.

On October 17-18 the junior author again visited Flint Creek. Numerous fish were seen jumping, indicating that immigration from Wheeler Reservoir was occurring. However, fish were still dying in numbers too large to be accounted for by natural mortality. Two large fish, one of which (a carp) was caught, were seen showing the same symptoms of poisoning which had been observed in August. L. L. Burns, an employee at the Hartselle Water Plant, stated that a few fish had been dying since the major kills occurred in August, although there had been no hard rains since that time. He had observed that rough fishes (bottom feeders) died continually, whereas deaths of the game species seemed to follow increases in turbidity accompanying the rapid drops in the water level which were associated with TVA regulatory activities.

A brief survey of the bottom organisms surviving in this silt-bottomed stream was also made at this time. Samples were taken at four stations scattered along approximately 12 miles of the lower portion of the stream. The dominant forms of animal life at all stations were oligochaetes (aquatic earthworms) and chironomid larvae. An unidentified small coleopterous larva was common, as were leeches. One snail, one isopod, and one small dragonfly naiad (Macromia sp.) were found. An adult mussel, the pink heel-splitter (Proptera alata megaptera Raf.), also was taken. Plankton samples contained very little animal life. It was obvious that enough food remained in, or had returned to, the creek to support some fish life, particularly bottom-feeding species, provided that the habitat was no longer hazardous because of the presence of insecticide which was presumed to have been deposited with the bottom silt. Unfortunately, no information was available concerning the populations of fish-food organisms in the stream prior to the poisoning or immediately after the heaviest fish kills in mid-August.

The first question raised in connection with these instances of insecticide pollution of streams concerned the safety of public water supplies. The water supply of Hartselle was taken from Flint Creek, and that of Albertville in Marshall County came from Short Creek. Extremely heavy fish kills had occurred in both. The water for these cities receives the conventional purification treatment of lime-alum coagulation, sedimentation, sand filtration, and chlorination. In these cities such treatment, plus the very low solubility of the halogenated hydrocarbons in the water, would assure, most probably, the almost complete absence of the poison from the water supplied to the consumer. However, where complete treatment is not given, or where treatment is not properly applied, it is conceivable that some insecticide might be carried in the water supplied to the consumer.

Quite obviously, then, the most serious result of this type of pollution, other than possible contamination of human water supplies, is the direct effect upon fish life and the indirect effect upon fish life through the destruction of some types of fish-food organisms. With the increasing use of organic insecticides in intensely farmed areas, this type of pollution promises to become a problem of considerable importance. If this proves to be the case, a clash of interests is inevitable.

It is the duty of the Public Health Service under Public Law 845, the Water Pollution Control Act of 1948, to cooperate with States in protecting the interests of all legitimate water users from detrimental effects of pollution. This includes, among other things, the utilization of streams as sources of public water supply, in the interests of fish and wildlife, and for recreational

5/J. C. Clarke and J. L. Crockett, Jr. Report of investigation of fish killed in Morgan and Marshall Counties as it relates to water supplies of Hartselle and Albertville, Alabama. Unpublished report, Bureau of Sanitation, Alabama State Department of Public Health, 1950.

purposes. It is urged, therefore, that the organizations whose duty it is to recommend methods of controlling crop pests make every effort to prevent further pollution of our streams and ponds with harmful amounts of insecticides. It is strongly indicated that a re-evaluation of the insecticides employed in cotton-insect control and of the recommendations for their use is warranted at this time.

SUMMARY

In August 1950, fish kills occurred in at least 15 streams in the Tennessee River Valley of Alabama. Investigations indicated that these kills resulted indirectly from the application of insecticides for the control of cotton insects. These are the first instances known to the authors in which extensive pollution of streams has resulted from the use of insecticides in agriculture.

In 1950, insecticides containing toxaphene, benzene hexachloride, DDT, and, later in the season, aldrin, became widely used on cotton for the first time in this area. The too frequent occurrence of showers during the dusting season made necessary the re-application of these insecticides at shorter than normal intervals and resulted inevitably in the build-up of large concentrations on the soil of cotton fields. Several heavy rains in August presumably washed into the streams of the area a quantity of insecticide that was apparently sufficient to eradicate all fish life from some streams and to cause lighter kills in others. These kills occurred soon after heavy rains and were associated with increases in the water levels of the streams and with increases in turbidity.

Stream pollution resulting from the employment of organic insecticides in agriculture may become an increasingly serious problem in areas where their use is expanding. It is suggested that the insecticides now employed for the control of cotton insects, and the recommendations for their use, be re-evaluated in an attempt to prevent further similar occurrences. It is also suggested that county agents and extension services should make every effort to prevent individual farmers from applying insecticides in excess of the quantities recommended.

ACKNOWLEDGMENTS

The authors wish to express their appreciation of the fine cooperation of A. N. Beck, Director of the Bureau of Sanitation, Alabama State Board of Health, and his staff; the Alabama Water Improvement Advisory Commission; the City Water Departments of Hartselle, Decatur, and Albertville, Alabama; L. F. Warrick, Chief of the Technical Services Branch, Division of Water Pollution Control, U. S. Public Health Service, Washington, D. C.; and Dr. W. T. Sumerford, Technical Development Services, Communicable Disease Center, U. S. Public Health Service, Savannah, Georgia. They also wish to thank the staff of the Tennessee Valley Authority, Decatur, Alabama, and the county agricultural agents from Lauderdale, Colbert, Lawrence, Morgan, Limestone, Madison, Marshall, and Jackson Counties, for their contributions of data.

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A NOMOGRAPH FOR RAPID BACK-CALCULATION OF FISH LENGTHS

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THE AGING of scales is only a part of fish growth studies. Much of the time required for these studies is spent on calculations of the lengths of fishes at the ends of past years of life. Several nomographic devices that have been developed recently facilitate these back-calculations. Most of the devices require measurement of the scale image, or recording of the scale-image dimensions on tagboard strips, with subsequent processing and calculation. Schuck (1949) describes a device for rapid back-calculation that requires the use of either tagboard strips or a special projector which eliminates the strips and allows these calculations to be made directly from the projected scale image. Hile (1950) describes a nomograph that can be adapted to any species having a nonlinear body-scale relationship. It requires the tagboard strips. Joeris (1950) describes a device that accomplishes rapid back-calculations directly from the scale image on the ground-glass screen of the standard scale projection machine.

A still easier and more rapid process of back-calculation is made possible by a simple nomograph used by fishery biologists in the Missouri Conservation Commission. It is an adaptation of the type of nomograph described by Carlander and Smith (1944), but it eliminates more of the tedious and time-consuming steps of the other methods. As adapted, it is made on a piece of cellulose-acetate sheeting, 0.06 inch thick, sold under the trade name Lumarith.[1/] Once the annuli have been located, the nomograph is placed directly over the scale image on the screen of the standard scale projector (Van Oosten, Deason, and Jobes, 1934). The back-calculations then take only a few seconds. One advantage of this nomograph, shared by some others, is that it is movable and can be adjusted to fit the stationary scale image. This process is much easier than that of adjusting the highly magnified scale image to a fixed nomograph.

In constructing the nomograph, one face of a sheet of plastic (13½ by 16 inches) is ruled transversely with single lines spaced 2 millimeters apart. Every tenth line is ruled double. These lines are scribed into the plastic. Clear margins of 3/4 inch are retained along the bottom, top, and right side. The sheet is then turned over, with the clear margin on the long side kept to the right, and numbers are scribed on the double lines as they show through. The lines are made on the face of the nomograph that is in contact with the ground-glass screen on the scale projector so that they are directly over the annuli of the image, thereby minimizing the error of parallax. The lowest double line is numbered 0, the next double line is 1, and so on. In figure 1 the double lines are shown as single lines somewhat bolder than those representing tenths of inches. Each double line should be numbered at three or four regular intervals across the face of the nomograph, as shown in figure 1. The lines should

[1/] Lumarith is sold by the Celanese Corporation of America, 180 Madison Avenue, New York 16, New York. Specifications: 60 gauge, color E050054 clear, finish AA class 1st. A harder plastic might be better, as this one tends to become scratched.

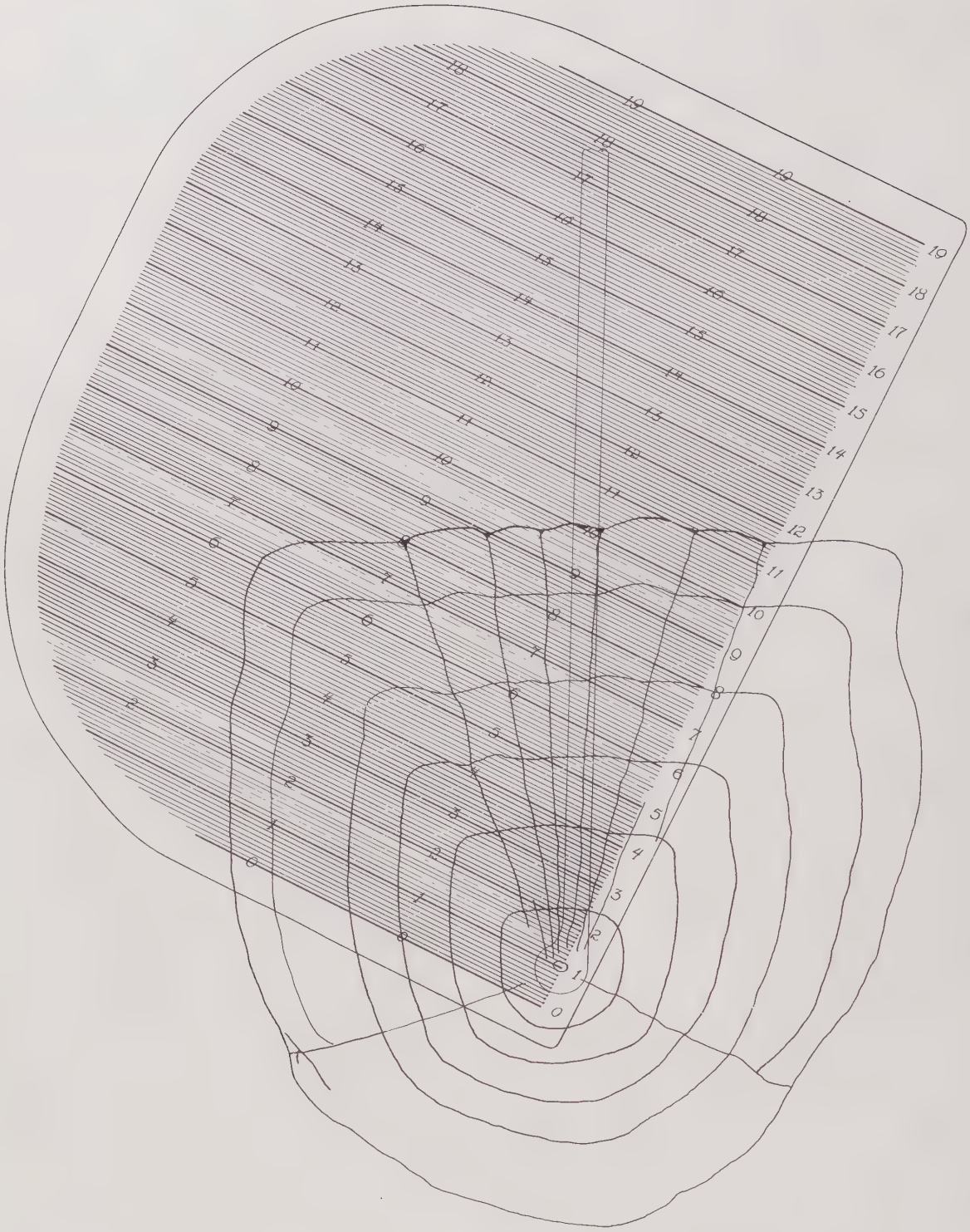


FIGURE 1.--The plastic overlay nomograph, its use, and the method of correction for a positive intercept on the body axis.

be fine and shallow so that they will neither obscure the scale image nor cause the plastic to warp. Both the lines and the numbers may be blackened with India ink or any other preparation for darkening graduations etched in glass.

A nomograph of this type may be constructed to fit scale images of any size and with any kind of relationship to the length of the fish. It is always necessary for the distance between the line representing a body length of 0 and the line that represents the length at capture of the fish to be exceeded by the dimension of the magnified scale that is used. The one should not exceed the other, however, by much more than about 25 percent, because the loss in accuracy increases as the difference between the measurements of body and scale increases. There is enough variation in size in the scales of a single species, or between species, so that the scale dimension used may be too small or too large for the nomograph. This difficulty may be overcome by the construction of another nomograph calibrated to suit the need. The second nomograph used in Missouri is marked like the one described, except that the double lines representing each inch of fish body length are 1 inch apart, and the intervening spaces are subdivided into tenths of inches. Both nomographs are intended for use with a scale magnification of 50X. It may be convenient to halve the scale of body values so that the distance between each double line represents 2 inches of body length. The nomograph is then usable on fish-scale images of two general sizes.

The first nomograph described has been satisfactory for back-calculations for smallmouth black bass, spotted bass, green sunfish, white bass, the carpsuckers, drum, orangespotted sunfish, large white crappie, small largemouth black bass, and a portion of the scales of the longear sunfish. When the scale of body values is halved, it may also be used for the walleye if a linear relationship is assumed. Because of their proportionally larger scales, white crappie under 10 inches, largemouth black bass over 9 inches in total length, rock bass, bluegill, and most of the longear sunfish fit the second nomograph better.

In use, the nomograph is placed over the scale image with the right end of the 0 line over the center of the focus. The whole instrument, pivoted on the focus center, is rotated to the right until the desired point on the anterior edge of the scale image is intersected by the line on the nomograph which corresponds to the body length of the fish. The nomograph line which cuts, or most nearly cuts, across the first annulus, along a line between the focus and the anterior edge of the scale image, is followed to its right end. Its value on the nomograph scale is the calculated length of the fish at the end of its first season of growth. Values may be interpolated if desired. The lengths at the ends of subsequent years are determined similarly. Rotation of the nomograph serves to "normalize" or "correct" the scale length to the average or theoretical scale length for a fish of any given size. This, in effect, makes the mathematical relationship a simple proportion.

A straight-edge strip of clear plastic may be used as a guide to insure alignment of the points on the annuli from which the back-calculations are made. The plastic strip should be laid on the nomograph and be pivoted on the 0 point.

In this method of back-calculation, a constant ratio of scale length to body length is assumed, although this relationship is seldom encountered. Much more frequently the plotted body-scale regression line intercepts the body axis at some point other than 0. If this is not taken into consideration, an error is introduced into the back-calculations, but this becomes progressively smaller as the size of the fish at calculated previous lengths becomes greater. Allowance for the value of the intercept of the body-scale line on the body axis, often considered to be the length of the fish at the time the scale is formed, is made simply. Instead of the 0 line, the right end of the nomograph line having the value of the intercept is set over the center of the focus, and the back-calculated lengths are read as already described. Fitted with a pin at its lower end, the plastic straight-edge guide is then pegged into small holes at the right ends of the cross lines. The pivot point

may then be varied as the 0, or intercept, point varies.

Figure 1 illustrates the nomograph, its use, and the method of correction for a positive intercept on the body axis. The scale pictured is a tracing of a scale from a fish of 10 inches total length. The body-scale relationship line for this species has an intercept at 1 inch. The back-calculated body lengths at the ends of the first, second, third, fourth, and fifth years were 2.20, 3.86, 5.27, 6.83, and 8.60 inches, respectively.

The assumption of a constant ratio of body length to scale length results in back-calculations accurate enough for many purposes. The correction described here makes the device quite accurate for back-calculations for species which have a linear, but not constant, body-scale relationship. Indeed, it results in a degree of accuracy that probably is sufficient for most management problems, even though the body-scale relationship may not be linear.

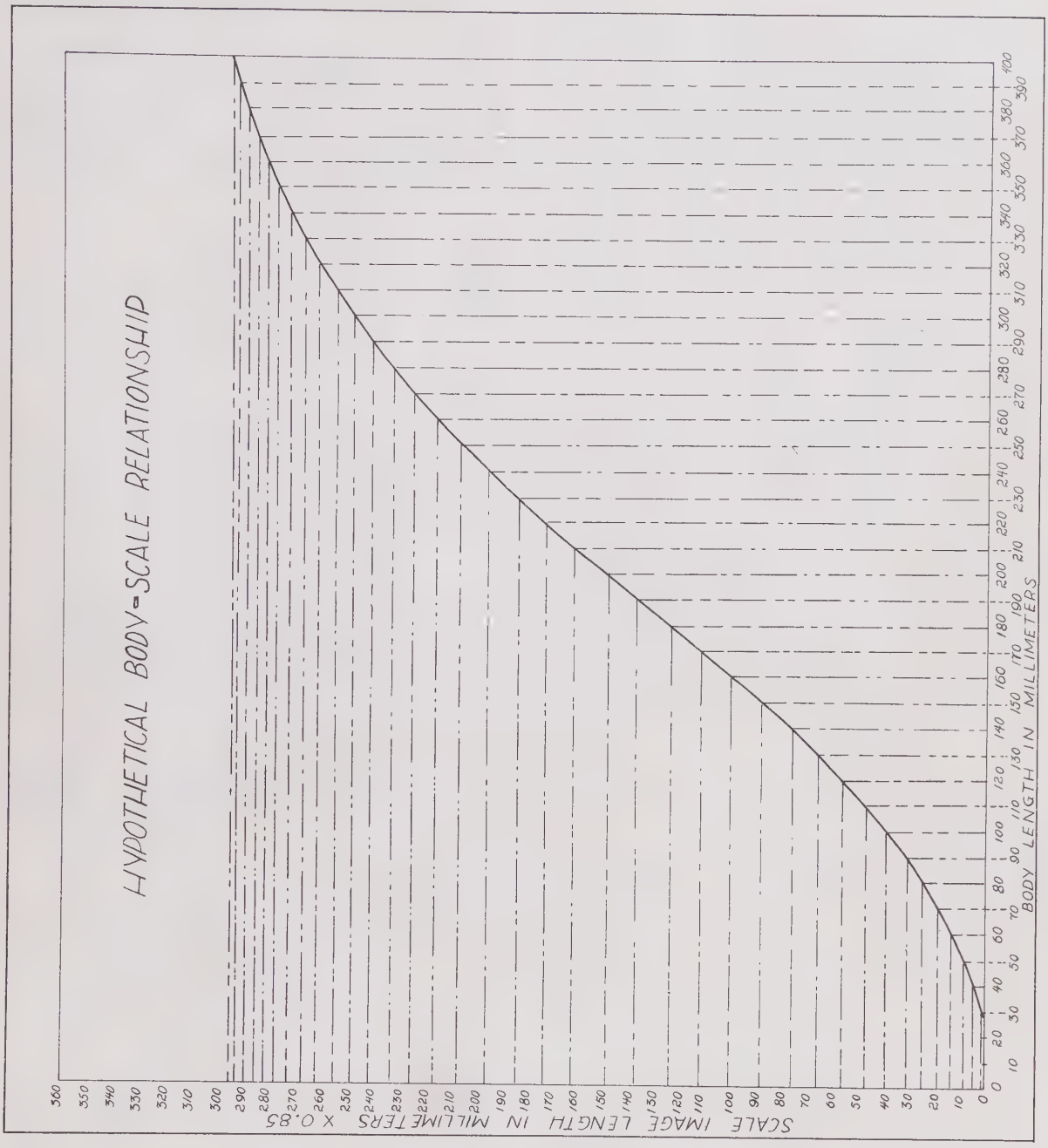
Nomographs also may be constructed for species having a nonlinear body-scale relationship, if greater accuracy is desired than may be attained with a nomograph designed for a linear relationship. The true relationship of the species considered must be determined by fitting a line to points representing body measurements plotted against scale measurements. The line may be fitted by inspection, or it may be fitted mathematically. A table of scale lengths corresponding to each 1/10-inch increase (or whatever other scale of measurement may be desired) in fish body length should be prepared. If the body-scale line was fitted by inspection, these scale image lengths must be determined by inspection of the graph showing this relationship. If the line was fitted mathematically, the scale lengths may be calculated by use of the equation expressing the relationship. This is really a table of "normal" scale lengths (Hile 1941) for any given body size. To allow for individual variations in sizes of scales and to make the nomograph fit all scales of the species, even those considerably smaller than the "normal," each scale image length in the table should be multiplied by a suitable factor. The reduction found satisfactory for scales of species studied in Missouri was 0.85. With very few exceptions, key scales, or scales from a key area, were larger than 85 percent of the "normal." The nomograph is ruled in accordance with the directions of Carlander and Smith (1944): "... the horizontal lines must first be considered as representing the 'normal' scale measurements, but the lines are not marked with these numbers. Instead, the /body/ lengths corresponding to the 'normal' scale measurements (from the table of solutions) are marked on the lines."

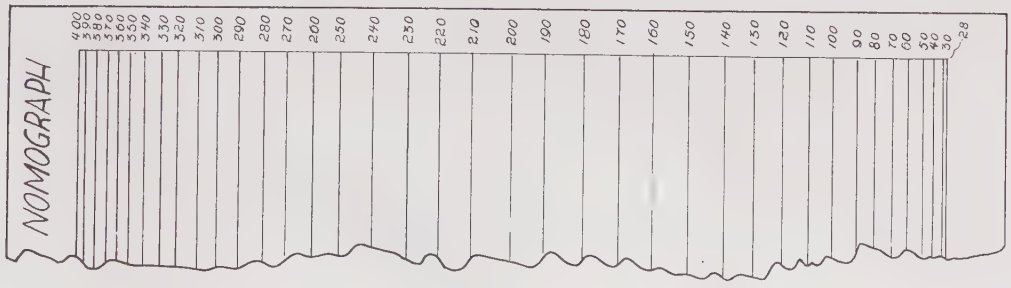
A nomograph for any type of body-scale relationship may be made more easily (figure 2). As before, each scale length to be plotted should be multiplied by a factor of 0.85. The scale lengths are then plotted against the corresponding body lengths and a line fitted to the points. The graph paper used should be ruled in the same system, English or metric, in which the study is being conducted. The plotted points should be the actual values (the scale X 0.85) of the body and scale measurements. Thus a group of fish with an average measurement of 200 millimeters total length and an average scale-image length of 100 millimeters would be plotted at a distance of 200 millimeters along the body axis and 85 millimeters along the scale axis.

For purposes of illustration, a somewhat exaggerated relationship is shown in figure 2. The graph of the relationship is fixed to a drawing board and lined up squarely with the sheet of plastic to be used. At desired intervals (10 millimeters in the figure) along the body axis, lines are raised to intercept the body-scale regression line. These lines are extended at right angles toward the sheet of plastic and are scribed into the plastic. Each line in the plastic is given the value of its point of origin on the body axis. The sheet is turned over before the numbers are scribed into the plastic. The result is a nomograph

(Opposite page)

FIGURE 2.--Method of construction of a plastic overlay nomograph for a species having a nonlinear body-scale relationship.


HYPOTHETICAL BODY-SCALE RELATIONSHIP
BODY LENGTH IN MILLIMETERS
SCALE IMAGE LENGTH IN MILLIMETERS X 0.85


NOMOGRAPH

perfectly fitted to the body-scale relationship of the fish being studied. The scale values are normalized when the nomograph is tilted, or rotated, to fit the scale image on the projector screen.

For greatest accuracy, two nomographs may be constructed, one with the scale value as measured, and the other with the scale value multiplied by the factor 0.85. Then, when the nomograph better fitted to the size of the scale is used, the degree of rotation and the error involved are minimized.

A simple test of the accuracy of back-calculations using the nomograph, as compared with another method, was made with the scales of 24 longear sunfish from the White River in Missouri. This species, in that section of the river, has a linear body-scale relationship and an intercept, or correction, of 0.4 inch. The total length of these fish ranged from 3.2 to 6.6 inches, and the scales had from one to four annuli. The back-calculations first were made with the nomograph. Then one of the standard methods was used. The scale dimensions were recorded on tagboard strips. These were measured, and the back-calculations were made by using the formula,

$$L_n = a + \frac{S_n}{S}(L - a),$$

where L is the length at capture; L_n is the length at any annulus, a is the length of the body-scale intercept on the body axis, S_n is the scale measurement to the annulus, and S is the length of the anterior radius of the scale. On the 24 scales there were 65 annuli for which back-calculations were made. The greatest difference in results from the two methods was 0.09 inch, and the average difference was 0.03 inch. Neither the size of the scale nor the nomograph used affected the results appreciably.

At first, the nomograph seems awkward; but after it has been tried on a few scales, the speed and accuracy with which it may be employed is greatly increased. Until one has used the nomograph, it is difficult to believe how much it does speed up the process of back-calculations of fish lengths.

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FEEDING FREQUENCY: ITS ROLE IN THE REARING OF BLUEBACK SALMON FINGERLINGS IN TROUGHS

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DURING THE 1949 rearing season, three experiments were conducted at the Leavenworth (Washington) Laboratory of the Fish and Wildlife Service to determine the optimum feeding frequencies for the rearing of blueback salmon (Oncorhynchus nerka) in troughs.

Considerable difference of opinion exists among fish-culturists as to the optimum feeding frequencies for small salmonoids. Recommendations made by the U. S. Commission of Fish and Fisheries (1897), Brunson (1923), Leach (1923), Surber (1926), Kibbe (1936), Cook (1936), Schaeperclaus (1933), and Davis (1946) vary widely, ranging from 4 to 20 feedings daily. The majority of fish-culturists recommend a reduction in the number of feedings per day as the fish attain greater size. Opinions differ, however, as to the optimum feeding frequency for each size group. Some authorities advise that the number of feedings be gradually reduced, as the fish grow, to four per day. Others maintain that the number should be reduced to three or two feedings daily for large fingerlings and one feeding per day for older fish.

This marked variance in recommendations by fish-culturists indicated that the optimum feeding frequencies for various sizes of salmon and trout had not been definitely established. Theory, rather than experimentation, was responsible for the procedures in use. It was apparent that studies should be undertaken to determine the optimum frequencies of feeding for fish throughout the normal growing season in both raceway and recirculating-type rearing tanks. These experiments should evaluate only such feeding frequencies as would be practical for use in fish-cultural stations operating on large-scale production and observing the usual 8-hour working day. The first experiments of this nature, conducted at the Leavenworth Laboratory, were designed to establish the optimum feeding frequencies for the rearing of blueback salmon in troughs. In these experiments, mortality and gain in weight were used to measure the differences.

METHODS

These experiments for determination of the optimum feeding frequencies for blueback salmon in troughs were conducted with four equal lots, each of which consisted of three troughs of fish. The fish in the first lot were fed eight times a day; those in the second lot, five times a day; those in the third lot, three times a day; and the fish in the fourth lot, once daily. When a significant difference in growth rate and/or mortality was encountered between certain lots, the experiment was discontinued and a new experiment was started with a fresh, uniform group of fish comparable in size to the normal, healthy fish of the previous experiment. This procedure was designed to reveal the optimum feeding frequency for each size group of fingerlings throughout the rearing season.

The first of these experiments was conducted with 207,464 fingerlings, all from a single day's egg take. The hatchery troughs used for the experiments were 16 feet long, 16½ inches wide, and had

an average water depth of 10 inches. The fish, averaging 4,322 per pound, were removed from the stacked trays when approximately 25 percent were capable of swimming up on a horizontal plane. They were then divided into four lots (51,866 fish per lot), and each lot was further divided into three troughs. The weight of each trough of fish at the time of stocking was 4 pounds.

The four lots of this experiment were designated 1-A, 2-A, 3-A, and 4-A. The fish in Lot 1-A were fed eight times daily; those in Lot 2-A, five times daily; those in Lot 3-A, three times daily; and the fish in Lot 4-A, once a day. The mean water temperature during the experiment was 44.3° F., the average biweekly temperatures rising gradually from 42.4° at the beginning of the experiment to 45.1° at the end.

The fish in the four lots were fed the same diet at all times. Any changes in diet composition, such as the addition of salt or meal, affected the four lots equally.

A feeding chart for blueback salmon, based on fish size, total weight, and water temperature, was used to determine the amount of food fed. Increases in the amount fed were made at biweekly intervals to conform to the gains in weight. Feeding was accomplished by means of a standard hand ricer that had 1/16-inch holes in the cup when the fish were small and 3/32-inch holes when the fish were larger and could take larger food particles.

The fish in all of the troughs were weighed at biweekly intervals to determine the gain in weight. Each trough of fish was drained for 15 seconds in the net before the weight was taken. Accurate records were kept on the mortalities in all troughs during the experiment.

The second experiment was conducted with 34,284 fingerlings from the same day's egg take as those in the first experiment. Except for a few minor changes, the methods used were the same as those used in the first experiment. The fish were divided, by means of the sampler described by Hewitt and Burrows (1948), into 12 homogeneous groups of 2,857 each and then were placed in 12 troughs. Each trough of fish weighed 5 pounds. The four lots, designated 1-B, 2-B, 3-B, and 4-B, consisted of three troughs each, as in the first experiment.

The mean water temperature during this experiment was 50.3° F., the average biweekly temperatures rising gradually from 45.4° at the beginning of the experiment to 55.8° at the end.

Throughout the second experiment, the fish were fed with a hand ricer that had 3/32-inch holes in the cup.

The third experiment was conducted with fingerlings from the same day's egg take as those in the first two experiments. The methods used were essentially the same as in the two earlier experiments, slight variations in procedure being due to the growth of the fish. The 13,716 fish were divided, by means of the same technique used in the second experiment, into 12 homogeneous groups of 1,143 fish each and were then placed in 12 troughs. The stocking weight was 10 pounds per trough. The four lots, each consisting of three troughs, were designated as 1-C, 2-C, 3-C, and 4-C.

The mean water temperature throughout this experiment was 51.9° F. During this experiment the average biweekly temperatures fell gradually from 56.6° at the beginning to 45.8° at the end.

Because of the large size of the fingerlings in this experiment, they were fed with a hand ricer that had 5/32-inch holes in the cup.

EXPERIMENTAL RESULTS

First Experiment

The results of the first experiment are shown in table 1. Analysis of variance (Snedecor 1946) of the average weight of individual fish per trough revealed that a significant difference existed at the 5-percent level between the fish fed eight times and those fed five times daily. Moreover, there was a highly significant difference between the fish fed five times and those fed three times, and between the fish fed three times and those fed once daily.

TABLE 1.--First experiment: Effect of feeding frequency on growth and survival of blueback salmon

(January 27 to May 25, 1949; average water temperature, 44.3° F.)

Lot	1-A	2-A	3-A	4-A
Feeding frequency ----------times daily--	8	5	3	1
Average weight per fish ----------grams-- at start	0.105	0.105	0.105	0.105
Number per pound at start ----------	4,322	4,322	4,322	4,322
Average weight per fish ----------grams-- at end[1/]	0.558	0.516	0.408	0.347
Number per pound at end ----------	813	924	1,112	1,308
Percent gain ----------	431.43	391.43	288.57	230.48
Conversion factor ----------	4.54	4.67	5.87	7.02
Average mortality per trough ----------	923	1,007	856	735
Percent mortality ----------	5.34	5.82	4.95	4.25

[1/] Least difference for significance at the 5-percent level between final mean weights: 0.032 grams.

Some of the factors causing these differences were quite easily recognized when the reactions of the fish to the various feeding frequencies were observed. Fish which were fed most frequently devoured their food promptly and consumed all of their food allotment. The fish which were fed five times daily required slightly more time for consumption of each food allotment. During this additional time, however, small amounts of food collected on and passed through the rear screens. The fish in the group which was fed three times daily did not consume the food readily. A considerable portion of the food remained on the surface of the water, where leaching noticeably removed some of the red color of the particles. A few fish fed on this bleached food from time to time between feedings, but a large portion of it drifted slowly through the rear screens. The fish which were fed once daily consumed only a small portion of the fresh food. The remaining food floated on the surface of the water and ultimately lost all of its red color. Although a few fish ate the bleached food, most of it went through the rear screens.

A more accurate check on the amount of food wasted per lot was obtained each morning by glancing into the rear portion of each trough. The bulk of the wasted food from the previous day's feeding could be found on the bottoms of the troughs, behind the rear screens. In Lot 1-A, there was none; in Lot 2-A, there was a small amount; in Lot 3-A, a considerable amount; and in Lot 4-A, a great deal. So marked were the differences in the amounts of food wasted that it was possible to distinguish one lot from the others merely by this simple comparison. These observations were confirmed by the conversion factors (table 1). The progressively higher conversion factors indicated that the less frequently the fish were fed, the greater was the amount of food required to produce a pound of fish.

Observation of the fish in the four lots showed that those in Lot 3-A and particularly in Lot 4-A, although normal and healthy in appearance, were stunted. Only the normal mortalities were taken throughout the experiment. Analysis of individual trough mortalities showed that no significant differences existed between lots or troughs.

Second Experiment

The results of the second experiment appear in table 2. Analysis of variance of the average weight of individual fish per trough showed that there were significant differences at the 5-percent level between the fish fed eight times and those fed five times, and between the fish fed five times and those fed three times daily. The difference between the groups fed three times and once daily was again highly significant.

TABLE 2.--Second experiment: Effect of feeding frequency on growth and survival of blueback salmon

(May 26 to August 17, 1949; average water temperature, 50.3° F.)

Lot	1-B	2-B	3-B	4-B
Feeding frequency ----------times daily--	8	5	3	1
Average weight per fish ----------grams-- at start	0.794	0.794	0.794	0.794
Number per pound at start ----------	571	571	571	571
Average weight per fish ----------grams-- at end[1/]	4.434	4.155	3.962	3.244
Number per pound at end ----------	102	109	116	140
Percent gain ----------	458.44	423.30	399.10	308.56
Conversion factor ----------	2.95	3.12	3.30	3.82
Average mortality per trough ----------	174	165	152	203
Percent mortality ----------	6.08	5.79	5.32	7.07

[1/] Least difference for significance at the 5-percent level between final mean weights: 0.156 grams.

The reactions of the larger fish to the various feeding frequencies differed somewhat from those of the first experiment. The fish which were fed eight times daily consumed their food even more rapidly than did the corresponding fish in the first experiment. These remained quite well distributed in the troughs, however, and did not appear to be concentrated entirely in the vicinity of the food. There was no evidence of leaching or food waste, as even the most minute fragments of food were quickly devoured and the water in the troughs remained clear. In spite of the prompt food consumption, all the fish grew rapidly and maintained their normal size variation with no evidence of starvation in the smaller fish. The fish which received five feedings daily ate their food nearly as rapidly as those given eight feedings. This group attacked the food particles a little more greedily, however, causing the water to become slightly clouded, and therefore wasted a small portion of the food. The fish which were fed three times required more time for consumption of their food allotment. They struck at the food ravenously and caused considerable cloudiness in the water. Showing preference for the larger food particles, the fish discarded the minute fragments: these comprised a great deal of this cloudiness. Whole masses of the floating food particles were driven about by the fish as they tried to satisfy their hunger. Those masses of food particles which happened to be driven toward the rear of the trough were forced through the rear screens and then were beyond reach of the fish. As a result of this voracity, a sizable portion of the food allotment was wasted. Though the fish which were fed once daily received a large allotment, they satisfied their appetites in about the same length of time as the fish which received three feedings. Waste of food was most evident in this group. They congregated near the water surface and attacked the food with such voracity that much of it was rendered unavailable. The water became so clouded with disintegrated food particles that the fish were nearly obscured. The smaller fragments of food, ignored by the fish, were permitted to drift through the rear screens; large masses of floating food particles also were driven through the screens by the feeding fish.

Daily comparisons of the amounts of wasted food which had settled behind the rear trough screens in the various lots of this experiment revealed the same pattern that appeared in the first experiment. Lot 1-B contained no wasted food; Lot 2-B, a slight amount; Lot 3-B, a moderate amount; and Lot 4-B, a large quantity. These observations were confirmed by the conversion factors (table 2). These factors increased with the reduction in the number of feedings per day.

Although all fish appeared sound and healthy and the mortalities were normal,

TABLE 3.--Third experiment: Effect of feeding frequency on growth and survival of blueback salmon

(August 18 to October 12, 1949; average water temperature, 51.9° F.)

Lot	1-C	2-C	3-C	4-C
Feeding frequency ----------times daily--	8	5	3	1
Average weight per fish ----------grams-- at start	3.972	3.972	3.972	3.972
Number per pound at start ----------	114	114	114	114
Average weight per fish ----------grams-- at end[1/]	6.421	6.344	6.188	5.826
Number per pound at end ----------	71	72	73	78
Percent gain ----------	61.66	59.72	55.79	46.68
Conversion factor ----------	5.23	5.37	5.61	6.61
Average mortality per trough ----------	3	3	1	4
Percent mortality ----------	0.26	0.26	0.09	0.35

[1/]Least difference for significance at the 5-percent level between final mean weights: 0.162 grams.

with no differences existing between lots, the variation in average size between lots was very conspicuous and revealed the stunting effects of infrequent feeding.

Third Experiment

The results of the third experiment are shown in table 3. Although the four lots followed the same pattern in relation to one another as did the corresponding lots in the first two experiments, analysis of variance of the average weight of individual fish per trough showed that the differences between the fish fed eight times and five times, and between those fed five times and three times, failed to attain significance at the 5-percent level. When the fish fed eight times were compared with those fed three times, however, the difference was significant. There was again a highly significant difference between the fish which received three feedings and those which were fed once daily. It is interesting to note that the first indication of a lack of correlation between feeding frequency and the growth produced appeared in this experiment with large fingerlings, which ranged from 114 to 71 per pound.

The fish in the four lots of this experiment reacted very much like the fish in the corresponding lots of the second experiment. Owing to the slower growth rate of the larger fish and the declining water temperatures, all conversion factors in this experiment (table 3) were somewhat higher than those of the second experiment (table 2). The fish which received eight feedings consumed their food allotment very rapidly, with no noticeable waste of food. They continued to grow normally, however, and there were no signs of starvation or stunting of the smaller fish in the group. The reactions of the fish that were fed five times were very similar to those of the first lot, with regard to the rate of consumption and lack of food waste. The fish consumed their larger food allotment promptly, and no cloudiness in the water or waste of food was noted. Rapid growth and normal size variation were maintained. The fish which received three feedings daily required a little more time for consumption of the food than the fish of the first two lots. Although the fish in this third lot struck at the food a little more vigorously and caused some cloudiness in the water, the floating food particles were consumed before they reached the rear portions of the troughs. Minute fragments of food, contributing to the clouded condition of the water, were ignored by these fish. The fish which received a single feeding reacted similarly to those of the corresponding lot in the second experiment. These fish gorged themselves to capacity with amazing rapidity but wasted a large portion of the food in the process. The water became extremely clouded, and the fish forced

large masses of floating food particles through the rear screens.

Daily examinations of the amounts of food deposited behind the rear trough screens in the four lots of this experiment showed that the picture here differed somewhat from the findings in the two previous experiments. Lots 1-C and 2-C contained no wasted food, but Lot 3-C contained a slight amount, and Lot 4-C had a large quantity. These differences in the amounts of food wasted in each lot were also reflected in the conversion factors (table 3).

The size variation among the fish in the four lots was less pronounced in this experiment than in the two earlier experiments, and the stunted appearance of the fish in the last two lots, although distinguishable, was much less apparent.

DISCUSSION

Although it is apparent from these experiments that trough-reared blueback salmon fingerlings which are fed at frequent intervals grow faster than those which are fed infrequently, positive identification of all of the factors causing the differences in growth is difficult.

When food is placed on the surface of the water, the fish seem to react to various stimuli which affect the efficient utilization of the food. One stimulus is the appearance of the fish-culturist, as it is characteristic of the blueback salmon that they quickly learn to congregate in anticipation of being fed. Another undoubted stimulus is the odor of the food when it is introduced into the water. The movement of the food by the current and by the activity of the feeding fish appears to be another stimulus. The fish seem to be attracted to the animated food particles: when this movement of the food ceases, the fish apparently lose interest in feeding and tend to ignore the food. This indicates that the reactions of fish in recirculating tanks, which impart a constant motion to the food, might be entirely different from the reactions of fish in troughs or raceways, where the food, driven by the inflowing water, drifts a short distance and then remains practically motionless. It is therefore entirely possible that fish in recirculating-type tanks may require less frequent feeding to produce the desired growth.

When fed at frequent intervals, the individual food allotments are small and rapidly consumed. This rapid consumption may be further expedited by the stimuli noted. The appearances of the fish-culturist and the resultant stimuli are frequent. The small food allotment is consumed before it has reached the portion of the trough where the surface current is reduced. As the food remains on the water but a short time, its odor is undiminished. It is logical to assume, then, that the food which these fish receive is of optimum quality because it has been subjected to a minimum of leaching. None is wasted by being left to drift through the rear screens.

When large fingerlings are fed frequently, they devour the food almost instantaneously, without any apparent waste. Since the entire group of fish continues to thrive on this frequent feeding, there is no evidence to support the theory that larger fish would consume all of the food allotment and thus cause starvation of the smaller, weaker individuals. It is entirely possible that all the fish may not eat at every feeding. This hypothesis is supported by the more even distribution of the frequently fed fish at feeding time.

The fish which are fed at infrequent intervals receive a large quantity of food at each feeding. When the fish are small, rapid consumption is difficult. They feed vigorously while the food is in motion, but their incentive to feed dies as the movement of the food slackens and their appetites become somewhat satisfied. It is also possible that their digestive tracts are too small to accommodate the large food allotment, so that they are forced to leave part of the food. As the surplus food which remains on the surface of the water bleaches, it is believed that certain of the valuable water-soluble nutrients are leached out and the quality of the food is thus reduced. Such leaching would also reduce the odor of the food and its power of attraction. By the time the desire to feed returns, part or all of the remaining food has

vanished through the rear trough screen. With little activity on the part of the fish-culturist around the trough, this stimulus is also small.

When the fish are larger, those fed at infrequent intervals dispose of their food allotment rapidly, before its movement ceases and while it is still fresh. All the fish crowd near the surface in a frantic effort to satisfy their hunger. Much of the food is wasted, either by being pulverized into minute fragments or by being driven forcefully through the rear screen. The concentration of fish at feeding time appears to be the primary factor in the efficient food utilization of large trough-reared blueback salmon. In ponds, particularly of the recirculating type, both the fish and the food are more evenly distributed and frequent feeding may not be necessary; in troughs, however, heavy concentrations of extremely voracious fish can be overcome only by more frequent feeding.

The factors which appear to be responsible for inefficient food utilization by infrequently fed small blueback salmon fingerlings in troughs are: (1) reduction of the stimuli to feed, and (2) the loss of some of the water-soluble nutrients from the food.

The principal factor causing inefficient food utilization by infrequently fed large blueback salmon fingerlings in troughs seems to be the food wastage created by the heavy concentration of the entire group of ravenous fish in the immediate vicinity of the food.

SUMMARY

Under the conditions of these experiments, the following conclusions can be drawn:

1. From the first feeding stage up to 100 per pound, blueback salmon fingerlings fed eight times daily make gains significantly greater than those of fish fed five times, and gains overwhelmingly greater than those of fish fed three times or once daily.

2. With fingerlings numbering 100 per pound and larger, the differences between gains made by fish fed eight times and gains made by fish fed five times, and between gains made by fish fed five times and gains made by fish fed three times, are so slight as to lack significance. The gains of fish fed eight times remain significantly greater than the gains of fish fed three times, however, and the difference between the gains of fish fed three times and those fed once daily is, in turn, highly significant.

3. No significant differences in mortality occur between fish fed at the various frequencies.

4. Frequently fed fingerlings utilize their food more efficiently than those fed infrequently, requiring less food to produce a pound of fish.

5. Frequent feeding of large fingerlings does not result in starvation or stunting of the smaller fish of the group.

6. The factors which appear to be responsible for inefficient food utilization by infrequently fed small fingerlings in troughs are: (1) reduction of the stimuli to feed, and (2) the loss of a portion of the water-soluble nutrients from the food.

7. The principal factor causing inefficient food utilization by infrequently fed large fingerlings in troughs seems to be the food wastage created by the concentration of the entire group of ravenous fish in the immediate vicinity of the food.

8. To secure the most efficient food utilization in troughs, fingerling blueback salmon should be fed eight times daily until they reach the approximate size of 100 per pound and at least five times daily thereafter.

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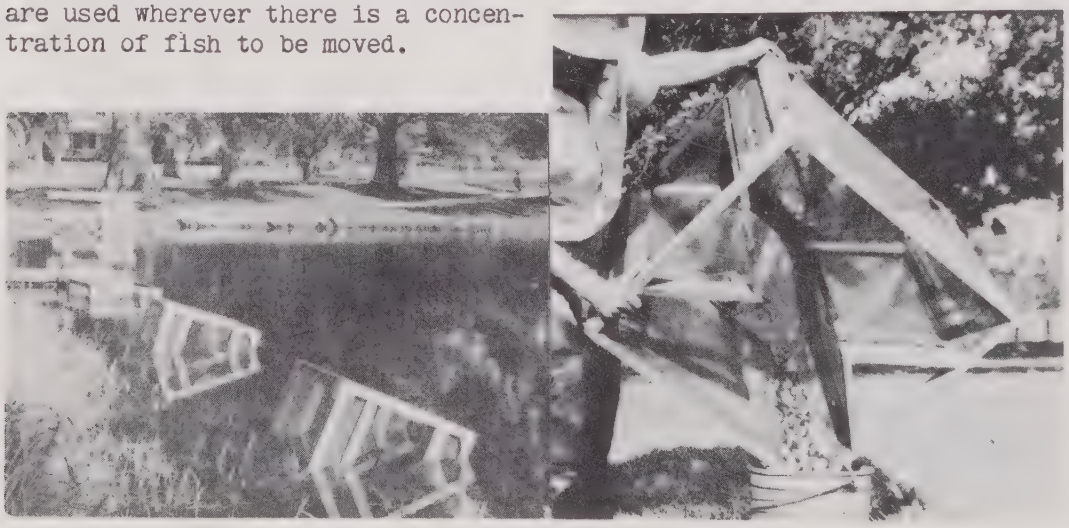
Fry traps with the "V" made of glass have been on trial at the U. S. Fish-Cultural Station at San Marcos, Texas. Apparently the fry will enter these traps more readily than those with the "V" made of wire. The traps are used wherever there is a concentration of fish to be moved.



VARIATION IN FISHING PRESSURE AND CATCH DURING VARIOUS PORTIONS OF THE TROUT SEASON ON SOME MICHIGAN TROUT WATERS

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IN THE COURSE of examining certain trout management proposals for the East Branch of the Au Gres River in Iosco County, Michigan, the question was raised as to what proportion of the angling pressure and what proportion of the total catch occurred in the several months of the trout season. To answer this question, intensive creel census data obtained in past years from several different trout waters in both the Lower and Upper Peninsulas of Michigan were examined.

The comparative material is provided by the intensive creel census records taken on: Guiley Pond (1940 to 1949, inclusive), a 1-3/4-acre trout pond on Guiley Creek where adult rainbow trout are confined after spawning, and which also contains a population of brook trout; on the trout streams located within the boundaries of the Rifle River Area (1945 to 1949, inclusive), where the brown trout is the dominant species, but all species are present; on the headwaters of Hunt Creek and on East Fish Lake (1940 to 1949, inclusive), where only the brook trout is found; and on portions of six Lower Peninsula trout streams (see tabular footnotes for streams and locations) during the 1939 trout season. The latter streams were variable as to the species of trout present, and all species were represented in the total catch. The Upper Peninsula streams for which we have information are the Fish Dam River (Delta County) and the East Branch of the Tahquamenon River (Chippewa County) in 1940. The only species in the East Branch is the brook trout. Both brook trout and brown trout entered the 1940 catch on the Fish Dam River.

For each trout water, and for the indicated years, the total pressure and the total catch observed have been divided into four 4-week periods and a shorter period of 16 to 24 days remaining at the end of each season. For Guiley Pond only, the catch was separated by species.

The numbers and percentage of the total pressure and of the total catch occurring in each of the arbitrary periods of the trout season are given in tables 1 and 2 for each of the waters in question. For the sake of brevity, only total figures are tabulated and combined into two main tables, inasmuch as the total figures yield the information sought. The records from which they were derived are filed in the offices of the Institute for Fisheries Research.

The length of the average trout season during the past 10 years had to be considered in this study, and it was found that there were 1,323 days in the seasons 1940 to 1949, inclusive, or an average season length of 132.3 days. Thus, each of the first four 4-week periods (four periods of an average length of 28 days) made up 21.16 percent, and the last 16 to 24 days (one period of an average length of 20.3 days) made up 15.3 percent. The 1939 and 1940 seasons were only 129 days in length, but inasmuch as this would have caused only slight changes in the percentages, these seasons have been regarded as 132.3 days in the tables and

TABLE 1.--Number (and percentage of total) of angling hours recorded in various parts of the trout season for various trout waters of Michigan, 1939 to 1949

Stream or lake, and years of intensive creel census	Number (and percentage of total) of angling hours					
	1st-4th weeks	5th-8th weeks	9th-12th weeks	13th-16th weeks	Last 16 to 24 days	Total hours of angling
Guiley Pond, 1940-49	10,510.25 (43.5+)	6,607.00 (27.3+)	3,493.25 (14.5+)	2,088.75 (8.6+)	1,458.50 (6.0+)	24,157.75
Rifle River Area, 1945-49	8,478.50 (41.1)	5,433.50 (26.3)	2,848.50 (13.8)	2,229.00 (10.8)	1,662.50 (8.0)	20,652.00
East Fish Lake, 1940-49	2,431.25 (38.6+)	1,362.50 (21.6+)	1,129.00 (17.9+)	745.75 (11.8+)	632.00 (10.0+)	6,300.50
Six Lower Peninsula streams, 1939 1/	9,714.50 (29.2+)	7,791.50 (23.4+)	6,530.25 (19.6+)	5,463.50 (16.4+)	3,749.75 (11.3+)	33,249.50
Hunt Creek, 1940-49	2,580.25 (26.0)	1,796.00 (18.1)	2,180.50 (22.0)	1,688.00 (17.0)	1,670.50 (16.8)	9,915.25
Two Upper Peninsula streams, 1940 2/	397.75 (32.2)	236.25 (19.1)	232.50 (18.8)	233.75 (18.9)	136.75 (11.0)	1,237.00
Percent of trout season in various periods 3/	21.2	21.2	21.2	21.2	15.3	---

1/ These data were obtained from the intensive creel censuses of 1939 on portions of the Pine River (Lake County), Pigeon River (Otsego County), North Branch Au Sable (Crawford County), Little Manistee (Lake County), Canada Creek (Presque Isle County), and the White River (Newaygo County).

2/ Intensive creel census data from portions of the Fish Dam River (Delta County) and the East Branch of the Tahquamenon River (Chippewa County).

3/ Percentage based on an average trout season of 132.3 days, which was the average for 1940-49. In 1939 and 1940, the percentage was slightly different, as the season in those years was only 129 days long, and each of the four 4-week periods represents 21.7 percent of the season and the last 17 days represent 13.2 percent of the season. Because this variance is slight and does not appear to change any trends or conclusions, no adjustments have been made.

TABLE 2.--Number (and percentage of total) of trout caught in various parts of the trout season in various trout waters of Michigan, 1939 to 1949

Stream or lake, and years of intensive creel census	Species trout taken	Number (and percentage of total) of trout caught					Total trout caught
		1st-4th weeks	5th-8th weeks	9th-12th weeks	13th-16th weeks	Last 16 to 24 days	
Guiley Pond, 1940-49	Rainbow	946 (54.3)	436 (25.0)	184 (10.6)	87 (5.0)	88 (5.1)	1,741
	Brook	223 (14.1)	472 (29.8)	425 (26.9)	256 (16.2)	206 (13.0)	1,582
Rifle River Area, 1945-49	All	1,515 (30.7)	1,829 (37.0)	745 (15.1)	464 (9.4)	384 (7.8)	4,937
East Fish Lake, 1940-49	Brook	933 (61.3)	197 (13.0)	152 (10.0)	121 (7.9)	118 (7.8)	1,521
Six Lower Peninsula streams, 1939 1/	All	3,756 (23.9)	3,912 (24.9)	3,291 (21.0)	2,993 (19.1)	1,741 (11.1)	15,693
Hunt Creek, 1940-49	Brook	926 (20.3)	752 (16.5)	1,153 (25.3)	1,029 (22.6)	699 (15.3)	4,559
Two Upper Peninsula streams, 1940 2/	Brook, brown	212 (18.7)	234 (20.7)	295 (26.1)	301 (26.6)	89 (7.9)	1,131
Percent of trout season in various periods 3/		21.2	21.2	21.2	21.2	15.3	---

1/ These data were obtained from the intensive creel censuses of 1939 on portions of the Pine River (Lake County), Pigeon River (Otsego County), North Branch Au Sable (Crawford County), Little Manistee (Lake County), Canada Creek (Presque Isle County), and the White River (Newaygo County).

2/ Intensive creel census data from portions of the Fish Dam River (Delta County) and the East Branch of the Tahquamenon River (Chippewa County).

3/ Percentage based on an average trout season of 132.3 days, which was the average for 1940-49. In 1939 and 1940, the percentage was slightly different, as the season in those years was only 129 days long, and each of the four 4-week periods represents 21.7 percent of the season and the last 17 days represent 13.2 percent of the season. Because this variance is slight and does not appear to change any trends or conclusions, no adjustments have been made.

the histogram (see figure). The figure presents in pictorial manner the results embodied in the tables.

GUILEY POND (1940-49)

The total seasonal angling pressures at Guiley Pond ranged from 582.50 hours (1948) to 7,009.25 hours (1949); the total catches ranged from 47 to 580 trout in those years. The great variation was the result of the failure of the dam until after the spawning run was over in 1948, and relatively few large rainbow trout were available. In 1949, the advertised transfer of approximately 1,000 adult rainbow trout from all parts of the Au Gres drainage attracted extremely large numbers of anglers.

Based on the 10-year totals and the division of these totals into the arbitrary time periods, 70.8* percent of the total pressure was exerted during the first 8 weeks (42.2 percent) of the trout season and was responsible for the removal of 79.3 percent of the total rainbow trout catch and 43.9 percent of the total brook trout catch.

Note that the percentage of the total rainbow trout catch diminished as the season progressed, whereas the percentage of the total brook trout catch was more steady (with a peak during the second and third periods) and followed more closely the percentage distribution of the various time periods within the average trout season.

RIFLE RIVER AREA TROUT STREAMS (1945-49)

In the 5 years after the establishment of intensive creel census operations on six trout streams of the Rifle River Area (Ogemaw County), a total of 20,652 hours of trout fishing yielded a total catch of 4,937 trout of all species (but mainly brown trout). The yearly total catches ranged from 418 (1945) to 1,547 (1947), and the total angling hours ranged between 3,397.5 (1945) and 5,061 (1948).

From the tabular material and from the histogram, it will be observed that the pressure pattern on the Rifle River Area streams follows closely that of Guiley Pond, particularly for the first three periods. The pattern of the removal of the total catch differs, however, in that the peak of the removal occurred in the second month of the season, rather than in the first 4-week period, and was followed by a noticeable drop in the third 4-week period and by gradual declines after that to the season's end.

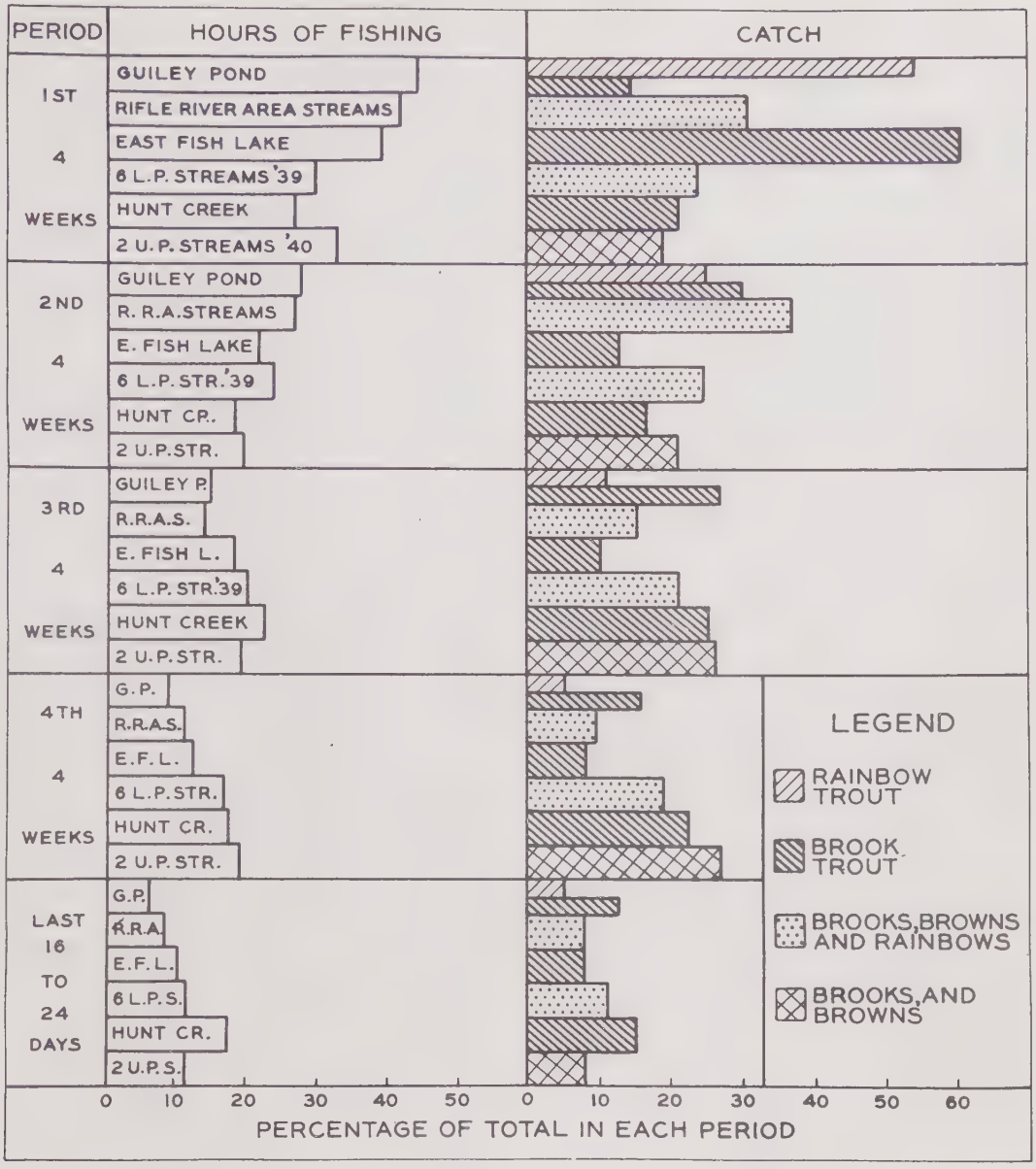
In the first 8 weeks (42.2 percent) of the average season, 67.4 percent of the total angling pressure had removed 67.7 percent of the total catch from the Rifle River Area trout streams.

EAST FISH LAKE (1940-49)

This 16-acre brook trout lake, lying in south-central Montmorency County, has been under intensive creel census operations during the identical span of years as Guiley Pond. East Fish Lake differs from Guiley Pond in that the former is larger, lies farther from Michigan's population centers, and is a natural trout lake and not an impoundment midway in a stream system. East Fish Lake is similar to Guiley Pond in that each has a limited population of large trout, the brook trout of East Fish Lake having much the same attraction for brook trout anglers as the rainbow trout of Guiley Pond have for rainbow trout fishermen.

Season catches ranged between 69 (1943) and 367 (1942) fish, whereas seasonal angling pressure ranged between 199.5 (1943) and 1,039.75 (1949) hours.

The pressure pattern for East Fish Lake is generally similar to that noted for Guiley Pond, and the removal pattern is also similar in character in that the greater part of the brook trout catch was removed in the first 4-week period. The reduction in angling pressure and in the catch in periods following the first reflects, to some degree, the tendency of the brook trout to refuse either fly or bait as the surface waters become warmer. By the end of the first 8 weeks of the average season, 60.2 percent of the total angling pressure had been expended on East Fish Lake and 74.3 percent of the total catch had been removed.



Percentage of total angling pressure and percentage of total catch during various periods of the average trout season. Data taken from tables 1 and 2.

EXPERIMENTAL SECTIONS, HUNT CREEK (1940-49)

The pattern of the angling pressure on Hunt Creek in the arbitrarily established time periods differs noticeably from the comparable data for trout waters already discussed. On Hunt Creek the angling pressure followed closely the percentage of the total time in the trout season within the various time periods. The same is true of the pattern of the catch.

Whereas in the other waters a greater part of the angling pressure and a greater part of the total catch were noted in the first 8 weeks of the season, on Hunt Creek 44.1 percent of the total angling pressure removed only 36.8 percent of the total catch during the first 8 weeks.

SIX LOWER PENINSULA TROUT STREAMS (1939)

During the 1939 season on these waters the pressure and removal patterns were similar to those noted for Hunt Creek. The percentages of the total pressure and total catch removed in the several periods (except the first period) were very close to the percentages of the trout season represented by the periods; in other words, the waters were fished at a rate consistent with the time divisions, and the proportion of the total catch removed in any period was close to the proportion of the season represented by any period.

TWO UPPER PENINSULA TROUT STREAMS (1940)

A limited number of data on the pressure and catch pattern over the trout season are available from the intensive creel censuses on portions of the Fish Dam River (Delta County) and on the East Branch of the Tahquamenon River (Chippewa County) during 1940.

The distribution of the angling pressure throughout the 1940 trout season on these two Upper Peninsula streams follows closely the pattern observed for the six Lower Peninsula trout streams in 1939. In the first 4-week period the percentage of the total pressure observed exceeded by about one-third the percentage of the season represented by the first period. In the following periods the percentages of total pressure were close to, but slightly less than, the percentage of the season represented by the respective time divisions. The distribution of the total catch over the 1940 season was very similar to that observed for the Hunt Creek data. The peak of the removal came in the third and fourth 4-week periods. This might be expected, as the brook trout dominated the catch in these two streams and also was the only species caught in Hunt Creek.

CONCLUSIONS

1. Trout streams, impoundments, or trout lakes with concentrations of large adult trout will receive the greater part of their angling pressure and will have the greater part of the season's total catch removed during the first 4 weeks of the trout season. Excellent examples are Guiley Pond, Platte River, East Fish Lake, and the trout lakes of the Pigeon River Forest and of Marquette County.

2. Where trout streams lie close to metropolitan centers, heavy early-season angling pressure may be anticipated. The pattern of the removal during the season will depend to a large degree on the species of trout present and their size. Examples of such streams are those of the Rifle River Area (Ogemaw County), the White River (Nawaygo County), and some of the smaller trout streams of Kent County.

3. Trout streams which are more distant from metropolitan centers, and which are also more or less normal as regards their trout population, are more likely to be fished at a uniform rate of pressure after the opening 4-week period. The percentage distribution of the total catch is usually higher in some 4-week period other than the first one. Some examples of streams in this category are Hunt Creek (Montmorency County), Fish Dam River (Delta County), the East Branch of the Tahquamenon River (Chippewa County), and Pigeon River (Otsego County).

4. Another factor in the distribution of angling pressure on Michigan trout waters is the occurrence of Decoration Day within the first 8 weeks. When this holiday falls on Friday or Monday, the streams are fished by many anglers who otherwise would not come north. Because the Michigan bass season opens on June 25, the angling pressure on the July 4 holiday tends to be more widely distributed over bass and trout waters, although some increase in trout-water angling pressure can be noted around July 4. The same situation appears to hold true for the Labor Day week end.

A NEW CHEMICAL TREATMENT APPARATUS

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A MARKED INCREASE in the numbers of anglers during the past 10 years has stimulated rotenone treatment of lakes and reservoirs in which rough fish have suppressed the development of a sport fishery. Waters varying widely in size, shape, and depth have been treated with considerable success in several States.

In California, larger waters were treated after World War II, when rotenone-bearing powders again became available at lower cost. During the past 2 years several projects have included lakes and reservoirs exceeding 300 acres in surface area, with volumes in excess of 10,000 acre feet. These have required mixing and distributing 4 to more than 13 tons of rotenone powder per project.

For large-scale treatments, a 250-gallon tank mounted on a platformed barge was used originally. Water was pumped into the tank from alongside, and, at first, powder and water were mixed by hand, aided by circulation from the inflow of water. Later, through the use of a centrifugal pump (capacity, 1 cubic foot per second), recirculation was applied through a still larger (500-gallon) tank. This change at once greatly speeded and facilitated mixing. The thin, batter-like fluid was continuously pumped from the mixing tank through a spraying apparatus. However, with the large tank, three pumps, suction and discharge lines, spraying apparatus, fuel and containers, tools, and other accessories aboard, load and work space on the barge was limited. Dust was also a major problem. It was evident that if rotenone powders in any quantity could be wet rapidly and spread simultaneously through a single unit, much space-taking equipment and some of the dust problem would be eliminated. Moreover, it was conceivable that the same source of power for wetting and spreading the powder could also be used to propel the barge. Drawing from earlier projects, the writer felt that a possible answer lay in application of the "jet" idea to the problem.

In December 1949, in preparation for rotenone treatment of 350-acre Lower Twin Lake, near Bridgeport, Mono County, California, the writer designed a new chemical treatment apparatus incorporating these ideas. Further simplification resulted in the basic unit shown in figure 1. In this unit a large tube was utilized as a mixing and propulsion chamber. This was equipped with two air-cooled Lawson outboard motors mounted tandem on adjustable transoms and a hopper through which powder was supplied to the tube. The assembled outfit was suspended for operation from parallel catwalks in the center of the barge, just under the water surface.

DESCRIPTION AND OPERATION

The Barge

In making up a barge, the writer has found oak plywood assault boats from Army surplus unsurpassed for stability, seaworthiness, flexibility, roominess, and load capacity. The boats are highly portable: they nest well, and four to eight can be carried on a 2½-ton truck. Each boat is 13 feet long, 5 feet wide, and has approximately 20 inches of freeboard. The bow is square across the beam but beveled, top to bottom, in order to repel wave action. The transoms are square, and pairs of boats may be pinned, stern to stern, with steel pins at the

outside corners of the transoms, making a single, pontoonlike unit 26 feet long. Two pairs of assault boats, spaced parallel about 4½ feet apart by a timbered deck securely lashed to the gunwales, have formed a single barge (figure 2).

The Tube

In the original assembly the tube is simply a 24-foot length of No. 10 gauge steel well casing, 14 inches in diameter (figure 1). A detachable screen covers the intake when the tube is operated in shallow water and about plant beds.

Atop, and centered on the tube, 5 feet from the intake end, a collar for the hopper is permanently fastened over a slot opening, 3 inches wide by 20 inches long. Outside dimensions of the collar are the same as the opening, with a height of 12 inches.

At points 14½ and 20½ feet, respectively, from the intake are cut elliptical openings, 9 inches long and 5 inches wide, for the outboard motor shafts. These remain uncovered in order to allow suction from the outboard propellers to draw much additional water into the tube.

Mounts of narrow channel iron for the outboard motors are welded laterally on top of the tube and just forward of the openings for the outboard motor shafts. Each vertical piece in the mount is slotted at the top, in order that the transom blocks (figure 1) may be adjusted and secured. Short braces of similar steel are welded at a downward angle forward from the mount. The blocks are of surfaced oak and are firmly fastened to the mounts at any height required for air-cooled outboard motor shafts.

FIGURE 1.--Basic unit of the new chemical treatment apparatus. V-hopper is on platform in left background.

FIGURE 2.--Assembled barge and treatment apparatus, suspended from parallel catwalks by adjustable angle irons, rides high at water surface when barge is empty.

FIGURE 3.--Barge and treatment apparatus as seen from forward on deck. Additional outboard power was necessary to drive the barge.

Slotted "belly straps" of narrow channel iron, for suspension of the chemical treatment assembly, are welded on the tube at four points spaced from the intake end. Eight pairs of angle irons connect to the belly straps on each side and make possible adjustable suspension from the catwalks on the barge (figures 2 and 3).

The Hopper

A V-hopper, equipped with a slotlike throat 20 inches deep, was made for attachment over the hopper collar. Outside dimensions of the hopper collar and inside dimensions of the throat are nearly identical. Thus the hopper fits snugly on the collar without additional braces or other attachment parts (figure 2).

Outboard Motors

Two air-cooled Lawson outboard motors mounted tandem in the tube were used for mixing and distribution and supplied some power to the barge. A 3½-horsepower motor was used in the forward position, and a 6-horsepower motor was used in the rear (figure 3). Propeller slippage and overheating of the forward motor might have resulted had motors of equal size been used or had this order been reversed. Both motors were equipped with 2-blade propellers, and the transoms were adjusted so that both propellers were centered in the tube.

Operation

The complete assembly for operation is shown in figure 2. With the barge

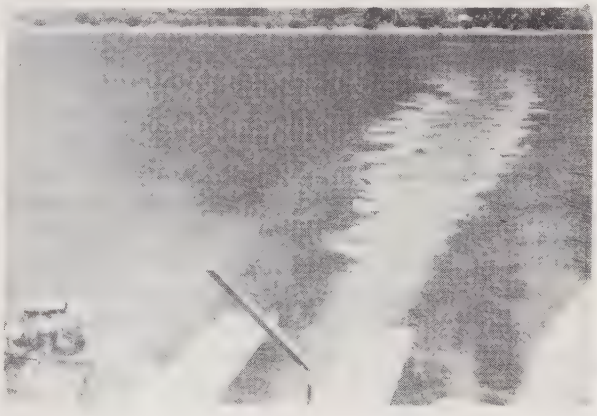

FIGURE 4.--Loading is begun near stern and carried forward. Combined weight of loaded barge and apparatus, about 5 tons.

FIGURE 5.--Contents of 50-pound paper bags of cube powder are fed into tube through the V-hopper at an average rate of about one per minute.

FIGURE 6.--Wetting and spreading of mix are simultaneous, as "jet" turbulence is accelerated by turbulence from outboards driving the barge.

(Photographs courtesy the author)

unloaded, the tube is suspended so that the top rides just above the surface of the water at the center. The intake end of the tube is elevated at a slight angle. This adjustment makes possible some suction, caused by air entering the tube, and speeds movement of powder through the hopper.

Loading is begun near the stern and carried forward. Combined weight of the loaded barge and apparatus is about 5 tons (figure 4).

With both outboard motors at full throttle, powder is fed through the slot-like throat of the hopper into the tube (figure 5). Rapid flow of water in the tube carries the powder back to the outboard propellers, where it is quickly churned into the water and forced through the tube outlet in a foglike jet of mix under the water surface.

In normal operation, cube powder was applied at Lower Twin Lake with the new treatment apparatus at an average rate of about 50 pounds per minute. Owing to the weight of the loaded barge, it was necessary to put two additional outboard motors on the stern for propulsion. One, a 5-horsepower Johnson, was fixed on the port transom of the barge; the second, a 15-horsepower Neptune, was used on the starboard side for the main source of power and for steering. The additional turbulence from these motors, driving the barge at about 7 miles per hour, accelerated mixing and spreading of the cube (figure 6).

Streams of cube were applied in lanes 100 to 200 feet apart, at right angles to the lake axis, about the lake margin, and in an oblique pattern across the lake in order to use wind drift to advantage. As in previous projects, the amounts of cube were, in general, apportioned to the lake by surface sections, and distribution was controlled by rate and amount of cube fed through the hopper.

At peak operation, the chemical tube required two men to supply the hopper and one man to operate the outboard motors. A crew of three operating a complete barge assembly was believed to be optimum on the basis of the experience at the Lower Twin Lake project, in which 13½ tons of cube was applied. A service (or shore) crew of two men was considered essential for help in assembly and disassembly, loading, and other service and supply for the treatment outfit.

As indicated elsewhere, thrust from the tube was insufficient to propel the barge; consequently, additional power was supplied to the barge for this purpose. The use of two 15-horsepower motors would be ideal. Increase of thrust from the tube, with additional benefit to powder mixing and distribution, is theoretically feasible without undue alteration of the tube.

Rotenone dust remained a problem despite the increased efficiency and output with the new apparatus. The use of Willson Monogoggles and wet standard gauze surgical masks, securely taped to the head and face, practically eliminated irritations to eyes and respiratory tract. However, by altering the shape of the present hopper and adding divided hinged covers, it is certain that in the future much flying dust can be avoided.

Cost

Assembly of the chemical treatment tube was done by local sheet-metal and blacksmith firms. Cost of the new apparatus as used at Lower Twin Lake (figure 2) may be detailed briefly as follows (3 percent State sales tax on material included):

Service (labor, forge work, welding, and cutting)	$108.00
Material (channel iron, plate and weld steel, bolts, etc.)	46.81
	$154.81

Cost of the well casing is not included here, as it was gratis. However, No. 1 reconditioned casing is quoted lately at approximately $2.85 per foot, allowing for freight; hence the initial cost of the original chemical tube would be about $223.21. [See note.]

Costs have been subject to change since this paper was received for publication, May 4, 1951. --The EDITORS.

SPECIFICATIONS

1. Barge: See text. In the fall of 1949, surplus barges of this type were available through several dealers in California at $75 each.

2. Tube: Well casing, 10 gauge, 14 inches in diameter, 24 feet long; procurable from dealers in Los Angeles and Bakersfield, California, at price per foot quoted (November 27, 1950).

3. Collar for hopper: Shape from 1/8-inch plate steel, 3 inches wide, 20 inches long, 12 inches high, dimensions OD; fasten to slot opening in the tube with 3/16- by 1/2-inch sheet-metal screws; slot opening is torch cut.

4. Hopper: See text; 16-gauge, galvanized sheet metal; top of bin is 2 feet wide by 3 feet long and, together with throat, is adjusted to height of 48 to 50 inches from top of tube.

5. Motor shaft openings: See text; elliptical, 9 inches long, 5 inches wide; torch cut.

6. Motor mounts: Each, two pieces of ¼- by 2½-inch channel iron, 22 inches high; two pieces welded opposite in vertical position; 11 inches apart (OD) and 2 inches from the forward edge of motor shaft opening. Vertical slots are 5/8 inch wide, 8 inches long, and accommodate ½- by 2-inch machine bolts. Braces for mounts are ¼- by 2½-inch channel iron welded at top of motor mounts and forward approximately 20 inches on the tube.

7. Transom blocks: Two; S 4 S oak, 1½ inches thick, 5 inches wide, and 10 inches long; drill and fasten in slotted vertical mounts with four ½- by 2-inch round-head machine bolts and lock washers.

8. Belly straps: Four; U-shaped, ¼- by 3-inch channel iron; slots 5/8 inch wide and 8 inches long; welded vertically to tube at points 4, 10, 13, and 18 feet, respectively, from intake end. Ends of straps project 6 inches above top of tube.

9. Angle irons: Eight; ¼- by 3-inch channel iron; horizontal arm is 12 inches long (drilled for two ½- by 3-inch lag screws); vertical arm is 24 inches long (drilled for two 1½- by ½-inch machine bolts).

10. Outboard motors: See text. Lawson, air-cooled, one 3½ horsepower and one 6 horsepower (larger motor in rear position) for chemical tube. Two 15-horsepower water-cooled Neptunes are ideal for propelling the barge; one of latter is fixed.

IMPROVEMENTS AND POSSIBILITIES

The treatment tube can be lengthened or shortened considerably as long as the power section remains balanced. In a later design the tube measures 13 feet over all. Confinement of two motors in tandem at a reasonable distance apart (5 to 6 feet) is necessary, as use of a single motor produces only partial mixing and causes rafting of powder at the water surface. If motors are placed too close, manual operation is hindered and the function of one motor is impaired by propeller slippage.

Projects of unusual size are now well within the scope of rough-fish control work, as it is possible to increase the size and capacity of a single treatment tube or to use the apparatus in multiples. For example, one barge would easily accommodate two rotenone tubes suspended from the sides by J-shaped belly straps. Thus the entire deck area would be free for additional load, and more than 150 pounds of powder per minute could be mixed and spread simultaneously. In the present design, capacity of the tube can be increased by widening the throat of the hopper and installing the tandem motors at a more forward point.

Early in the design of the present tube it was realized that much weight could be eliminated through the use of duralumin or similar aluminum alloy. The original assembly, including the hopper and outboard motors, weighs 670 pounds: the use of duralumin, with shortening of the tube, would reduce this to less than 300 pounds.

Testing and use of the apparatus showed that confinement of the outboard motors promoted propeller slippage. Additional water, therefore, will be admitted to the motors in the future by putting a flare in the intake end of the tube, by leaving the motor shaft openings uncovered, and by having four water scoops permanently built into the sides of the tube, one pair just ahead of each motor shaft opening.

Distribution with the new chemical tube is primarily just below the water surface. When depth application is desired, it can be accomplished by lateral pumping attachments directly into the rearmost section of the tube.

Though yet untried, the use of 3-blade propellers would further benefit mixing, distribution, and thrust.

The present tube is now more easily handled as the result of a division at the center and a sleeve connection. The sections are secured end to end on assembly of the tube at four radial points.

In general, features of the new chemical treatment apparatus can be summarized as follows:

1. It eliminates much excess equipment and creates an effective and relatively simple treatment unit.
2. It provides more deck space for load, personnel, and work movement.
3. It combines into one synchronous operation the wetting or mixing of water with rotenone powder and the distribution.
4. It increases the efficiency in preparing and spreading commercial rotenone powder in any quantity and is thus applicable over a much wider range of rough-fish control projects.
5. The new assembly is built from common parts and material and can be made up rapidly (in 2 days at most).
6. It is quickly and easily assembled and disassembled and is readily transported.
7. It is operable by any new crew in which at least one man can operate an outboard motor.

ACKNOWLEDGMENTS

Grateful acknowledgment is due Mr. Elbridge H. Hartshorn and, particularly, Mr. Claude Walborn, both of Bishop, California, for helpful hints in making the chemical tube.

SAFETY MEASURES IN THE USE OF ELECTRIC-POWERED SCRUBBERS

The operator of an electric-powered pond-scrubber, as described in the July issue of The Progressive Fish-Culturist ("Pond-Scrubbing Machine With Single Brush" or "Pond-Scrubbing Machine With Double Brush"), should take due precautions to avoid injury from electric shock if the machine is used in a pond or raceway that contains water. The motor should be of a moisture-proof type, and the cord should be protected from abrasions that might result in a short circuit.

THE TREATMENT FREQUENCY AND CONCENTRATION NECESSARY FOR ADEQUATE PROPHYLAXIS WITH PYRIDYLMERCURIC ACETATE FOR THE CONTROL OF BACTERIAL GILL DISEASE

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AN EXPERIMENT on blueback salmon (Oncorhynchus nerka) was conducted at the Leavenworth (Washington) Laboratory of the U. S. Fish and Wildlife Service to determine the frequency of treatment and concentration of pyridylmercuric acetate necessary to control bacterial gill disease in Foster-Lucas ponds.

The work of Rucker (1948), Snieszko (1949), and Burrows and Palmer (1949) indicated that pyridylmercuric acetate at a concentration of 1:500,000 for a 1-hour exposure period was effective for the control of bacterial gill disease. When used as a prophylactic, most disinfectants need not be used at the same concentration that would be required to treat an established epizootic. In the experiment described here, it was found that either the treatment interval or the concentration of pyridylmercuric acetate could be varied from the established weekly treatment at a 1:500,000 concentration and still maintain effective prophylaxis.

Four Foster-Lucas ponds, 76 feet long by 17 feet wide, were stocked with comparable blueback salmon fingerlings. The initial weight placed in each pond was 152 pounds. All ponds received the same diet and they were handled in an identical manner with the exception of the frequency and concentration of the pyridylmercuric acetate prophylaxis.

Prior to the initiation of the experiment, all the fish had received weekly prophylactic treatments with pyridylmercuric acetate at a concentration of 1:500,000 in a 1-hour exposure for a period of approximately 5 months. Starting on June 29, Pond 301 received biweekly treatments at a 1:1,000,000 concentration; Pond 302, biweekly treatments at a 1:500,000 concentration; Pond 303, weekly treatments at a 1:1,000,000 concentration; and Pond 304, weekly treatments at a 1:500,000 concentration. A fifth pond, stocked with a comparable poundage, was used as a control. All treatments were administered by means of the dry method of application as developed by Burrows and Palmer (1949).

On the 68th day of the experiment, 2 days prior to the scheduled fifth biweekly exposure at a 1:1,000,000 concentration, the fish in Pond 301 showed evidence of having bacterial gill disease. Microscopic examination of affected fish the following day confirmed the general symptoms by the disclosure of the characteristic filamentous bacteria associated with the disease. The regular treatment was advanced 1 day, and for the remainder of the experimental period this pond received weekly treatments at a 1:1,000,000 concentration. This concentration and frequency of treatment were effective in the control of the incipient epidemic.

No outbreak of bacterial gill disease occurred in the ponds which received the other prophylactic treatments throughout the course of the 13-week experimental period. At the conclusion of the experiment, the weight of fish per pond averaged 877 pounds. Because Pond 301 was treated promptly at the outset of the epidemic, no increase in mortality due to the disease occurred. As a result, there was no

significant difference in the mortality in the ponds used in the experiment.

In this experiment, as the weight of fish in Pond 301 increased to approximately 700 pounds, the biweekly treatment with pyridylmercuric acetate at a concentration of 1:1,000,000 was inadequate for the control of the disease. The control pond developed gill disease 1 month earlier than the treated pond and 3 weeks after prophylaxis was discontinued. These results and those of previous years indicate that bacterial gill disease is endemic in the water supply of the Leavenworth Station. From the present experiment it may be concluded that the biweekly 1:1,000,000 prophylaxis was effective in the control of bacterial gill disease as long as the poundage of fish was below a 700-pound maximum. (This weight limit is applicable only to this size and type of pond.) Computed on the basis of pounds of fish per cubic foot of water, the poundage at which biweekly treatments at a 1:1,000,000 concentration of pyridylmercuric acetate were no longer effective was 0.185 pound per cubic foot.

The upper limits of adequate prophylaxis with either weekly treatments at a 1:1,000,000 concentration or biweekly treatments at a 1:500,000 concentration were not determined from this experiment. The upper limits are, however, in excess of 0.232 pound per cubic foot of water.

The fact that blueback salmon reared in Foster-Lucas ponds are more susceptible to bacterial gill disease than are those reared in either circular pools or raceways, lends credence to the belief that the frequency of prophylaxis and strength of treatment satisfactory for Foster-Lucas ponds would be more than adequate for the control of bacterial gill disease in either raceways or circular pools. On this basis it may be concluded that either biweekly treatments at a 1:500,000 concentration of pyridylmercuric acetate or weekly treatments at a 1:1,000,000 concentration would be effective for the control of bacterial gill disease in Foster-Lucas, raceway, or circular rearing ponds where the fish concentrations approximate and possibly exceed 0.232 pound per cubic foot of water. It is indicated, also, that biweekly treatments at a 1:1,000,000 concentration would provide adequate prophylaxis for fish concentrations below 0.185 pound per cubic foot.

The results of this experiment, applied to production procedures, represent a saving of 50 percent in the cost of the disinfectant and, if the biweekly treatment interval is used, a reduction of 50 percent in the time required for treatment.

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Samples from 19 bottom sampling stations encompassing 57 square feet of representative riffle areas in the trout stream waters of the Shenandoah National Park contained about 56 fish-food organisms to the square foot.

THE FEEDING OF COOKED CARP TO HATCHERY TROUT IN COLORADO

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EVERY YEAR there are numerous requests for information regarding the carp diet fed to trout in Colorado State hatcheries and rearing units. This means is being utilized to answer some of these questions.

Carp are seined under contract by commercial seiners in the numerous irrigation reservoirs in the eastern part of the State. The contracted price is 3½¢ per pound delivered to the production unit. [See note.]

The carp are frozen for storage. The only preparation required is washing to remove gravel and debris which would interfere with future grinding.

Most of the rearing units are equipped with low-pressure (10 to 15 pounds) steam-jacket cookers. The capacity of these ranges from around 1,200 pounds to 2,000 pounds. Several hatcheries still utilize an open-kettle type of cooker, but these are gradually being replaced because of the long cooking time required in their use.

Food formulas and methods of preparation vary somewhat with the individual hatchery superintendent. In general, the diets consist of 80-90 percent carp, 10-20 percent cereals, and ½-2 percent salt.

The carp, with salt and a small amount of water, are placed in the cookers and cooked until soft. The time varies with the efficiency of the cooker and the size of the carp. Average time in cooking is 6 to 8 hours.

After the carp are cooked, the cereals are added. There is usually enough heat left in the vats to cook the cereal, but occasionally additional cooking is necessary. The cereal commonly used is rolled oats, although wheat shorts and other cereal byproducts have been utilized.

The cooked mixture is allowed to cool and then is ground. The amount of grinding is dependent upon the size of fish to be fed. Cooling the mixture properly before grinding and before feeding is important to the texture of the feed. If the feed is not adequately cooled, it will "milk" too much in the water and there will be a subsequent loss in food value.

Small fish are started on liver and, as they grow, are gradually put on the carp diet. The complete transition to carp occurs when the fish are about 2 inches in length.

There are two principal disadvantages to the carp diet. Carp contain a high quantity of natural oils. Trout kept on a straight carp diet tend to get quite fat and eventually have a fatty liver condition. This is possibly due to a choline deficiency.

There also appears to be a B-complex vitamin deficiency or vitamin-inhibiting factor which occasionally causes a dietary blue-slime disease. This is offset somewhat by supplementing the diet with liver and melts and by adding 5 percent brewers' yeast to the diet.

Conversion factors are not so low with carp feed as with liver or melts. In general, the conversion runs between 4 and 6 pounds of food per pound of trout. Under controlled conditions this conversion has been lowered to slightly more than 3 and compared favorably with a fresh meat diet.

Advantages lie primarily in the cheap cost of the diet. Costs per pound of

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Costs have been subject to change since this paper was received for publication, March 7, 1951.--The EDITORS.

fish gained have been as low as 12¢.

The fish like the food and grow quite rapidly on it. Practically all the production units raise fish to lengths of 7 to 9 inches in 1 year.

It should be pointed out that carp must be cooked before being fed to trout. Workers in the nutritional field, such as Dr. A. M. Phillips of the U. S. Fish and Wildlife Service, have shown that raw carp have a deleterious effect on trout. This inhibiting factor seems to be removed by the cooking process.

This paper is presented primarily for informational purposes, and no recommendations are intended. The carp in Colorado are providing invaluable assistance to the trout-fishing sportsman. Approximately 1,125 tons of this nongame fish are utilized annually to produce some 225 tons of trout for distribution in the waters of the State.

PLASTIC HATCHING BOX FOR STOCKING TROUT AND SALMON

This transparent box, conceived by R. Vibert, Directeur des Eaux et Forêts, Oloron Ste. Marie, France, is being used extensively to stock trout and salmon in European waters.

Containing 1,000 eyed eggs, the box is put into a hole (10 to 30 centimeters deep) dug in the river gravel-bed, and then covered with gravel, a piece of impervious paper to keep out silt, and then coarser gravel. The baffled openings on all sides of the box allow passage for the alevins. Best results are obtained in clear, rapid waters. In water that has a large amount of silt, a simple upstream disposition transforming the current into a stickle or shallow rapid is advisable.

Advantages of the box appear to be twofold: the complete obscurity during hatching precludes the contamination of living eggs with mold from dead eggs, and the alevins reach the fry stage under natural conditions in the gravel of the river--so that the fry need undergo no period of adjustment from hatchery conditions to those of the water being stocked.

French authorities made 150 tests in 20 different rivers during 1948-49 and reported 85 to 100 percent efficiency in limpid waters. The results are now awaited from 5 million eggs planted in these boxes during December 1950 and January 1951.

THE DESIGN OF AN ELECTRIC SHOCKER BOAT

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THE ELECTRIC SHOCKER is becoming a very important piece of equipment in fishery work. Its use in streams for general collecting and for fish population estimates has been adopted readily by most workers. The present article describes a utility boat that has been used with success in Michigan during the past few years with both AC and DC shocking equipment. The advantages of this boat over the variety of lightweight metal, wood, or plastic boats offered on the market are primarily those of size and cost. The boat is constructed of marine plywood and weighs about 55 pounds, and the cost of materials at the time of writing is about $25.

The boat can be constructed simply by securing the materials and special tools listed here and then following the assembling procedure.

Materials and Special Tools

1 piece	marine plywood, 8' x 35" x 1/4"
2 pieces	" " 8' x 12" x 1/4"
2 "	" " 8' x 9" x 1/4"
7 "	hardwood frame, 8' x 3/4" x 1"
6 "	" keel, 8' x 3/4" x 2"
3 gross	flat-head brass screws, size 7, 3/4"
1/4 pound	waterproof glue
8	metal corner braces, 3"
2	eyebolts, 1/4"
3 or more	metal clamps, 4-1/2'
2 " "	C clamps
1	9' plank, 2" x 10" or larger
1	1/16 drill and hand drill for screw holes
1	plane or wood rasp for trimming

Procedure

Construct each side according to measurements in figure 1. After marking points for width, draw curve for bottom, using another piece of plywood for a marking edge. Glue and clamp top frame piece flush with top edge and fasten. Place two vertical frames 28 inches from each end and bend the bottom frame in place and fasten. Allow the plywood to overlap the bottom frame 1/4 inch. Fasten all the short vertical frame pieces last, four on each side.

Construct the bottom as in figure 2 by turning the sides bottom edge up and parallel to each other. Place the two spreaders at 28 inches from each end on the vertical frames and clamp sides together across each end. Do not fasten spreaders permanently. Spring ends inward until they measure 26 inches outside. Lay the 35-inch piece of plywood across for bottom. Clamp each end of the plywood down on the side pieces and mark along the outside edge. Remove and cut out the bottom piece. Fasten the bottom in place by releasing clamps until bottom drops into place on the bottom frames. Clamp and fasten bottom, working across boat from one end to the opposite end. Fasten a piece across each end on the inside bottom and turn the boat right side up.

Construct the ends from measurements in figure 3. Cut the end pieces from plywood 9 inches wide. Fasten across bottom frame, working up each side frame.

Contribution from the Michigan Institute for Fisheries Research.

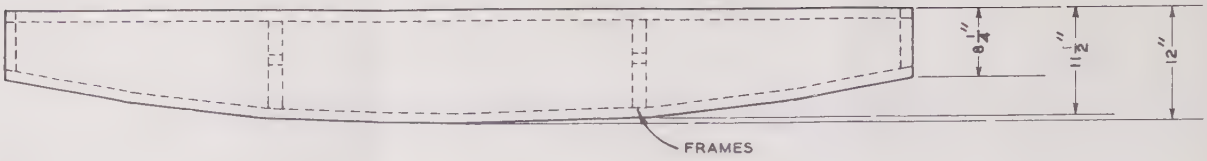


FIG. 1 SIDE VIEW
KEELS OMITTED

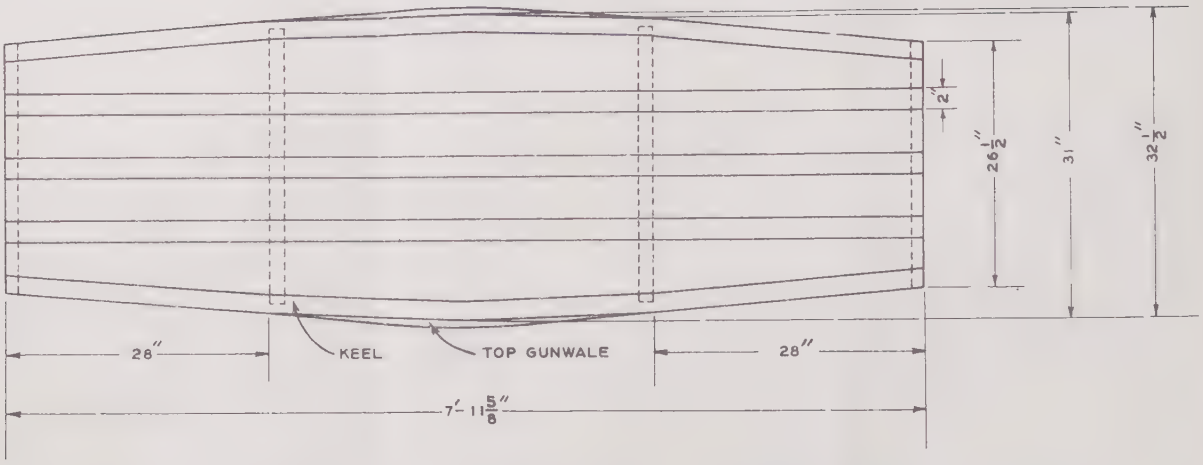


FIG. 2 BOTTOM VIEW

Use a clamp across top edge at each end to spring sides in place before fastening ends. Fasten the top frame piece in place last. Use a frame 2 inches wide at the top edge in the bow. The two eyebolts are fastened to this piece for towing. Another piece 2 inches wide may be fastened to the outside on the bottom edge of the bow to prevent chafing and to give added support. There is enough extra material listed for keels to use for these two pieces.

The stringers are fastened with corner braces 5 inches down from the gunwale on vertical frames. These should be fastened securely, as they are used to lift the boat as well as to give the boat support and shape. Each corner is given more support by fastening a corner brace inside and across top frames.

Fasten the keels last as shown in figures 2 and 3. Draw a center line both inside and outside along the bottom for each keel. Clamp the keels in place, turn the boat on edge, and fasten the keels from inside.

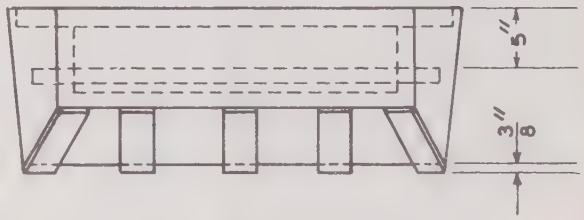


FIG. 3 END VIEW
SHOWING KEELS

Construction Hints

Oak is generally used for hardwood frames and keels. The 9-foot plank is used on sawhorses for clamping bottom section in place. Scraps of wood of various lengths can be worked under clamp jaws to help hold construction pieces together for fastening. Screws should be placed about 3-1/2 inches apart and countersunk. Speed up the screw fastening with an electric drill or wood brace with screwdriver attachments. The keels can

be cut from full 8-foot flooring. Saw tongue and groove off and re-saw. The finished strips will be about 3/8 inch thick depending upon the width of saw cut. Cover all areas that are fastened together with glue. Do not make sides more than 7 feet 11-3/4 inches total length. The plywood comes in 8-foot lengths, and the curve of the bottom shortens the total length. Fasten on the inside of the boat all frame pieces except the extra piece at bottom of bow and keels. Working the clamps close together across the bottom will give the sections a better fit.

Modifications for Direct Current Use

Boats constructed for carrying AC electric equipment can be modified easily. Cover the area between any two keels with a sheet of copper or copper screen. Cut it long enough to overlap an inch on each end. Fasten the strip down under the keels and under the extra outside bow strip. Use tacks to fasten the stern edge.

For added convenience, drill a small hole near top edge of bow, run a heavy insulated wire from a negative plug to the copper strip, and solder.

UNDERWATER LIGHT AS MANAGEMENT TOOL

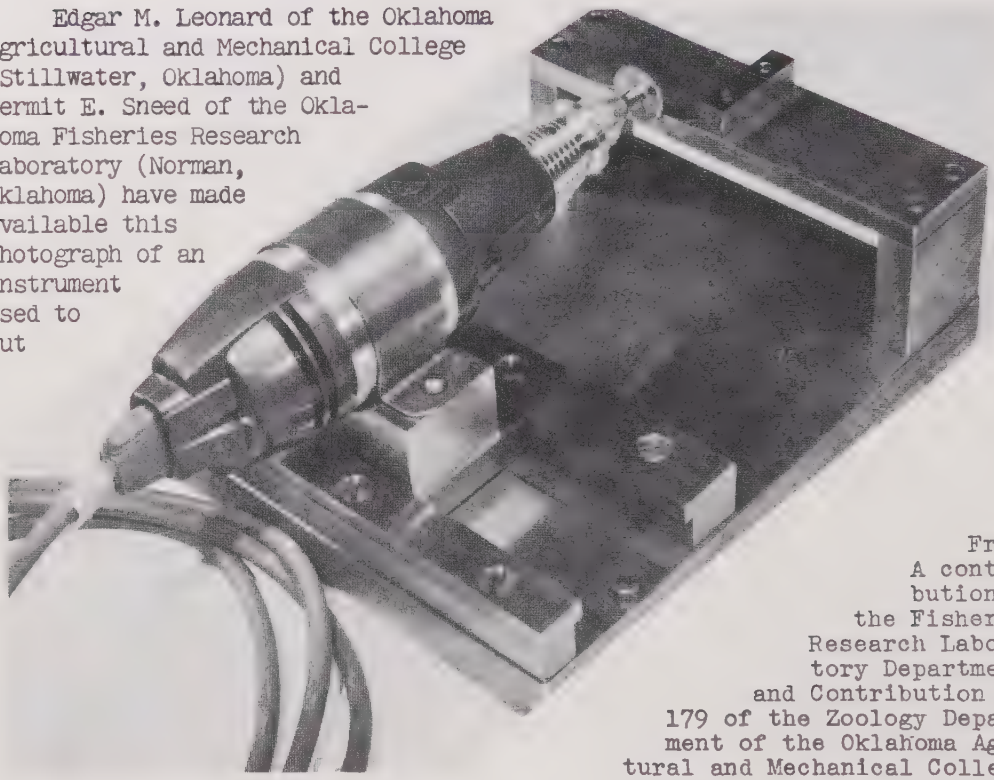
Stanley Lievense, District Fisheries Supervisor, Michigan Department of Conservation, stationed at Baldwin, Michigan, suggests that an underwater light be added to our present lake and stream management tools. As most of the portable lights that he has seen used for night fishery activities have been above-surface lights and have usually consisted of gasoline-burning flare or mantle types with reflectors, he submits the following description of a simply constructed light for underwater use:

> The parts consist of a 6-volt wet-cell battery, two battery clamps, two lengths of copper wire (each about 6 feet), a lamp socket, and an ordinary 6-volt 50-candlepower single-filament single-contact spotlight bulb. The permanent connections are made by affixing the clamps and socket to the wires. The bulb is put in the socket, and the socket is held in place temporarily with a piece of rope underneath the bow of the boat; after the bulb is in place underwater, the circuit can be completed by attaching the clamps to the battery. Maximum illumination will be obtained by using a white-bottomed boat, in contrast to one painted black.

Such a light, Lievense points out, can be used at night to observe the extent of a fish kill, the success of an introduction, fish concentrations, or the locations of certain species, as well as to study fish habits. With the light and a hand spear, it will be possible to take specimens that might be missed by the conventional collection tools and to secure fish for valid stomach samples.

INSTRUMENT TO CUT CATFISH SPINES FOR AGE AND GROWTH DETERMINATIONS

Edgar M. Leonard of the Oklahoma Agricultural and Mechanical College (Stillwater, Oklahoma) and Kermit E. Sneed of the Oklahoma Fisheries Research Laboratory (Norman, Oklahoma) have made available this photograph of an instrument used to cut



From: A contribution of the Fisheries Research Laboratory Department, and Contribution No. 179 of the Zoology Department of the Oklahoma Agritural and Mechanical College.

thin cross sections of catfish spines for age and growth determinations. The pilot model of the cutter was designed by James McArthur, formerly of the Oklahoma Fisheries Research Laboratory.

The cutter consists essentially of a saw mounted on a sliding carriage which moves in ways on the base of the instrument. Many of the electric-power tools used by hobbyists can be utilized here if they are adapted to accommodate a circular saw about 1 inch in diameter. The instrument shown here was built entirely of steel to secure greater stability, but aluminum could be substituted except in parts subject to friction.

At the 80th annual meeting of the American Fisheries Society, where Sneed presented a paper describing the instrument, he stated that the cross sections should be taken just beyond the terminus of the groove in the pectoral spine in order to retain all the annular rings. The thickness of these sections will depend upon many factors, but in general the sections should be cut as thin as possible. The cross sections need not be ground or polished if they are examined under water in a shallow dish. An ocular micrometer with a movable cross hair may be used to measure the distance between the annular rings.

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